NASA CONTRACTOR REPORT

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STUDY OF QUIET TURBOFAN STOL AIRCRAFT FOR SHORT-HAUL TRANSPORTATION

Final Report, Volume I, Summary

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16. Abstract

Conceptual designs of Quiet Turbofan STOL Short-Haul Transport Aircraft for the mid-1980 time period are developed and analyzed to determine their technical, operational, and economic feasibility. A matrix of aircraft using various high-lift systems and design parameters are considered as follows:

Lift Systems
- Externally Blown Flap
- Upper Surface Blown Jet Flap
- Augmentor Wing
- Internally Blown Jet Flap
- Mechanical Flap

Design Parameters
- Passenger Capacity: 50, 100, 150, 200
- Field Length (ft.): 1500, 2000, 3000, 4000 (Sea Level, 95°F)
- Range: 500 Nautical Miles
- Noise: 95 EPNdB at 500 ft. sideline

Variations in aircraft characteristics, airport geometry and location, and operational techniques are analyzed systematically to determine their effects on the market, operating economics, and community acceptance. In these studies, the total systems approach is considered to be critically important in analyzing the potential of STOL aircraft to reduce noise pollution and alleviate the increasing air corridor and airport congestion.

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FOREWORD

This document is one of six volumes which comprises the final report of a contract study performed for NASA, "Study of Quiet Turbofan STOL Aircraft for Short-Haul Transportation," by the Douglas Aircraft Company, McDonnell Douglas Corporation.

The NASA technical monitor for the study was R. C. Savin, Advanced Concepts and Missions Division, Ames Research Center, California.

The Douglas program manager for the study was L. S. Rochte. He was assisted by study managers who prepared the analyses contained in the technical volumes shown below.

Volume I	Summary	
Volume II	Aircraft	L. V. Malthan
Volume III	Airports	J. K. Moore
Volume IV	Markets	G. R. Morrissey
Volume V	Economics	M. M. Platte
Volume VI	Systems Analysis	J. Seif

The participation of the airline subcontractors, (Air California, Allegheny, American and United), throughout the study was coordinated by J. A. Stern.

The one year study, initiated in May 1972, was divided into two phases. The final report covers both phases.

SUMMARY

This report summarizes the main features of a one year program of analysis for NASA on the Study of Quiet Turbofan STOL Aircraft for Short-Haul Transportation (STOL Systems Study) which was completed in May 1973. During Phase I, more than 200 parametric aircraft (propulsive-lift and high-lift mechanical flap designs) and several parametric short-haul systems were investigated based on an initial set of criteria specified in the statement of work. This effort resulted in the selection of eight of the most promising candidate aircraft and a number of representative short-haul transportation systems for detailed analysis. The detailed studies of these aircraft and systems in Phase II were performed in a realistic operating environment which established a meaningful basis for evaluating their social and economic viability in a representative national model for short-haul transportation during the 1980-1990 period.

The framework of the study encompassed five interdisciplinary areas: market, aircraft, airport, economic and systems analysis. In-depth studies in these areas were based on technology and environmental considerations consistent with 1980-1990 commercial operating systems. Approximately one-half of the total study effort was devoted to aircraft analysis and the other half to the remaining areas.

Engine data for this study were provided by Detroit Diesel Allison and General Electric under contract to NASA-Lewis Research Center on the quiet, clean STOL experimental engine (QCSEE) program.

A comprehensive systems evaluation approach used throughout the study led to the following major conclusions:

- STOL AIRCRAFT CHARACTERISTICS
  - STOL transportation systems appear to be economically viable.
  - Mechanical flap aircraft improve with field length and are competitive with propulsive lift aircraft for 3000 foot field length.
  - A payload of approximately 150 passengers is the preferred size.
  - The development of a new high-bypass-ratio, quiet, clean, variable pitch fan engine in the 20,000 pound thrust class is required.
- MARKETS
  - The United States civil market for a 150 passenger STOL short-haul aircraft is estimated to be:
    - 420 aircraft by 1985 for the representative national system which includes high-, medium- and lower-density city-pairs.
    - 240 aircraft by 1985 and 320 aircraft by 1990 based on the higher-density city-pairs alone.
  - The foreign civil market for the same aircraft, based on the higher-density city-pairs alone, is estimated to be 320 aircraft by 1985 and 545 aircraft by 1990.
- NOISE
  - All STOL designs provided significant noise reduction in comparison with current CTOL aircraft.
  - The cost of noise reduction runs high -- particularly to reach the noise goal specified in this study (95 PNdB at 500 feet sideline distance).

- IMPLEMENTATION
  - Existing airports are favorably located to implement a STOL system.
  - The earliest date for implementation of propulsive-lift aircraft in an operating system is the 1982-83 period.

The assistance and viewpoints of the airline operators were obtained to assure airline realism in the study. Four airlines were placed under contract (Air California, Allegheny, American and United) and actively participated throughout the study from its initiation to the review of the final report. Their principal comments are summarized in Section 7.

Critical technology areas, which require research and development emphasis, were identified from an evaluation of the study results. Advancements in propulsion, aerodynamics and operating techniques are needed and will contribute significantly in achieving socially and economically viable STOL short-haul transport operations. Recommended technology areas requiring research include:

- Noise criteria
- Noise of powered-lift systems
- Far-field aerodynamic noise
- STOL operational techniques
- Engine development
- Thrust reversers
- Ground effects (takeoff and landing)

- Hybrid configurations
- Ice protection
- Operational factors (airport environment)

Although not a critical technology requirement, advanced composites have great potential for improvement of STOL transportation system economics. Expected payoffs include reduced weight, improved manufacturability and increased reliability through improved fatigue behavior. A separate study of the application of composite materials to civil STOL aircraft is being conducted for NASA, as an add-on to this study contract, and the report will be published in July 1973.

Community socio-psychological research is urgently needed to provide a better understanding of the problems associated with community acceptance of airports and related transportation requirements.

INTRODUCTION

PERSPECTIVE

System studies, which include all pertinent elements and activities of quiet STOL short-haul transportation operations, are an effective means of demonstrating that the airplanes being analyzed are practical designs capable of operating in a realistic transportation pattern. All principle ingredients of the total transportation system are thus considered in analyzing the potential of quiet turbofan STOL airplanes to assist in reducing noise and alleviating the increasing air corridor and airport congestion that is causing deterioration of the quality, operating costs and effectiveness of air transportation. The systems approach is of particular importance in analyzing these complex problems in response to the broad objectives of the basic study which are to:

- o Determine the relationships between STOL characteristics and the economic and social viability of short-haul air transportation.
- o Identify critical technology problems requiring solution prior to introduction of STOL short-haul systems.
- o Define representative aircraft configurations, characteristics and costs.
- o Identify high payoff technology for improving STOL short-haul systems.

Viewed against these objectives, it is noted that the NASA work statement specifies that ". . . study is not intended to define actual

transport airplanes nor dictate the selection of specific lift concepts. Rather, the required design studies are needed to provide a realistic basis for systems analysis and technology assessment."

GENERAL STUDY PROCEDURES

The study discipline areas are shown in Figure 1 which outlines the typical tasks studied in designing and evaluating the short-haul candidate aircraft and transportation systems.

The general procedures for accomplishing this are described below:

- The operational period for the STOL short-haul transportation systems being examined was established as 1980-1990 to cover the likely period of introduction and growth of the systems throughout the United States.

- Seven regions, typical of United States short-haul markets, were analyzed: Chicago - Northeast - California - Southern - Southeast - Northwest - Hawaii (Figure 2).

- The market demand for each of these regions was forecast for the 1980-1990 period and patronage analyses were conducted to examine the tradeoffs among aircraft characteristics and system operating parameters.

- Airport system operational concepts were evaluated with STOL runways at: air carrier, general aviation, military and new STOL airports.

STUDY DISCIPLINE AREAS

AIRCRAFT	AIRPORT	MARKET	ECONOMICS	SYSTEMS
o LIFT CONCEPTS o TRADE STUDIES o DESIGN STUDIES o CRITICAL TECHNOLOGY	o SITE SELECTION o AIRPORT/ACFT COMPATIBILITY o COMMUNITY ACCEPT. o CONGESTION RELIEF	o REGIONS o PATRONAGE MODEL o COMPETING MODES o MARKETS – UNITED STATES – FOREIGN – MILITARY	o DOC/IOC/ROI o DEV AND PROD. o FARE POLICIES o TOTAL SYSTEM COST o MILITARY COMMON.	o OPER. SCENARIO o ROUTE ANALYSIS o FLEET EVALUATION o SERVICE CONCEPTS o STOL IMPLEMENT/ EVOLUTION

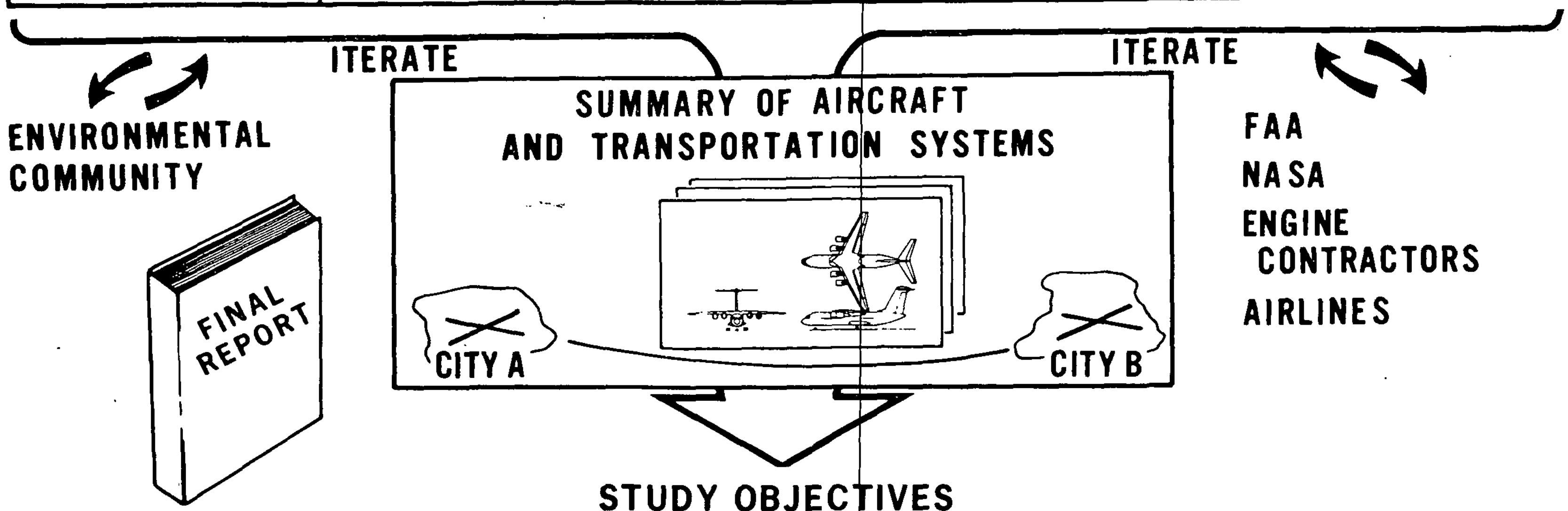

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FIGURE 1.

REPRESENTATIVE SHORT-HAUL MARKET REGIONS

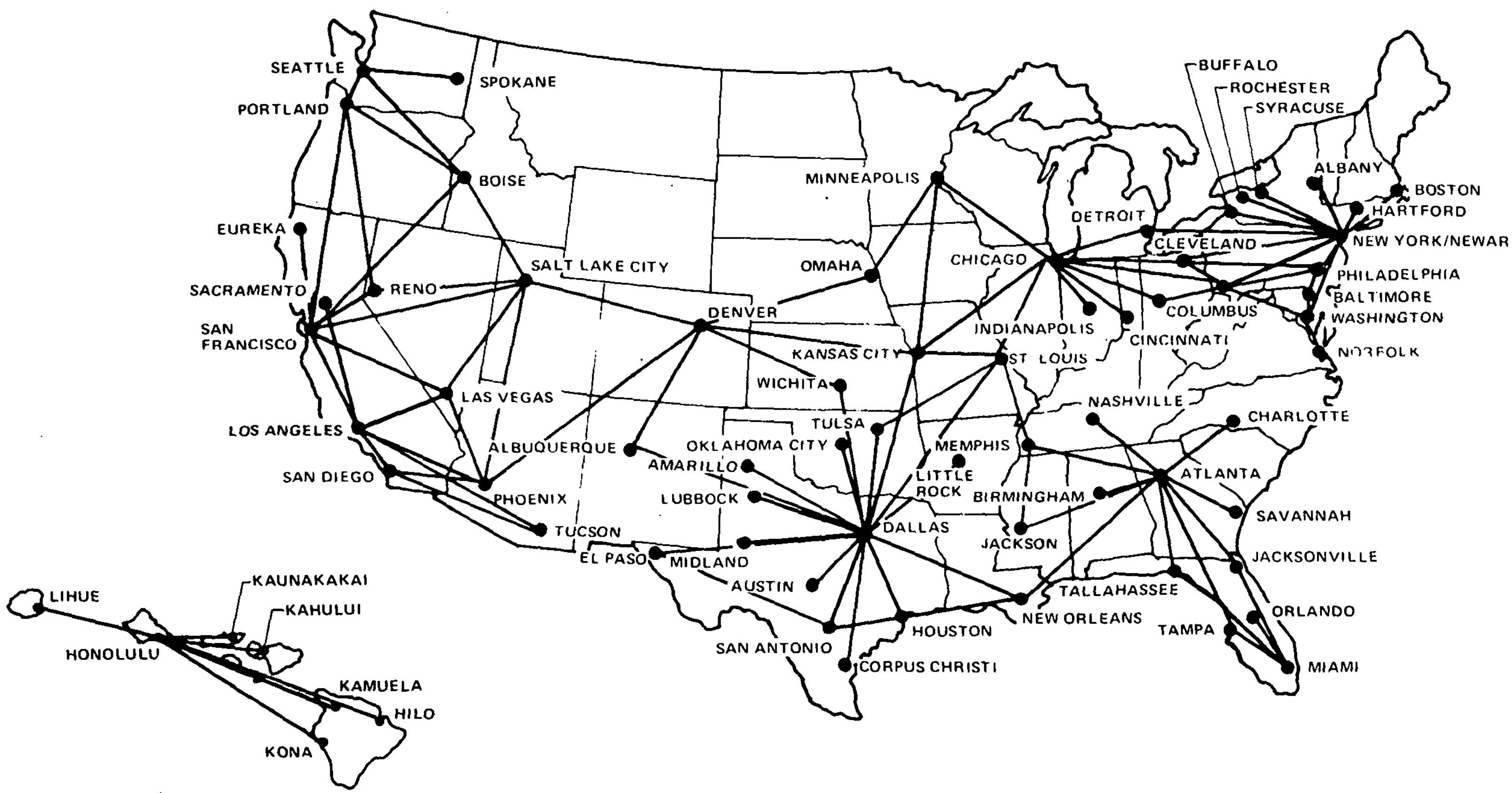

FIGURE 2

PR3-STOL !791A

- Engine data from the NASA QCSEE contractors, Allison and General Electric, were analyzed.

- More than 200 propulsive-lift and high-lift mechanical flap aircraft were designed.

- These aircraft were screened and eight of the most attractive concepts were selected for detailed design and systems evaluation on representative commercial airline route networks in the several market regions (Figure 3).

- Tradeoff investigations were conducted of various aircraft parameters such as noise, cruise speed and configuration to determine their effect on performance and operating cost.

- Economic analyses of the aircraft were conducted and comparative evaluations made of competing designs operating in a realistic airline environment.

- Community acceptance was assessed including field investigations of representative STOL airport settings to measure the magnitude of the community problem.

- Congestion relief was evaluated at the major hub airports.

During the acoustic/engine cycle tradeoff investigations in Phase II, it was found that both takeoff gross weight and operating cost were significantly reduced when the noise goal of the study (95 EPNdB at 500 feet sideline distance) was slightly relaxed. Two families of aircraft, therefore,

PHASE II AIRCRAFT

FIELD LENGTH FT.(METERS)	PASSENGERS		
	100	150	200
2000 (610)		AUGMENTOR WING EXTERNALLY BLOWN FLAP UPPER SURFACE BLOWING	
3000 (915)	EXTERNALLY BLOWN FLAP	EXTERNALLY BLOWN FLAP MECHANICAL FLAP	EXTERNALLY BLOWN FLAP
4000 (1220)		MECHANICAL FLAP	

FIGURE 3

PR2-STOL-1024 E

were analyzed in Phase II according to the following description:

Systems Analysis Aircraft: 95 EPNdB at 500 feet

Final Design Aircraft: 95 to 98 EPNdB at 500 feet

To be fully effective, the major components of a STOL transportation system should work in harmony. These components (aircraft, markets, airports and ATC) interact decisively on each other and gains in one field may be nullified by obsolete procedures in another (Figure 4). All services, therefore, should be designed to a high level of performance. The operational scenario which guided the study, and which was based on these components, consisted of the following:

- o Unconstrained short-haul passenger demand.
- o A fleet of STOL aircraft in an operational setting.
- o Airline route networks of an operating system.
- o Airports selected for short-haul operations with emphasis on community acceptance.
- o Advanced procedures for air traffic control and airport terminal operations unique to STOL aircraft.

Variations in aircraft characteristics, airport geometry and location, and operational techniques were analyzed systematically to determine their effects on the market, economic and community acceptance. It is emphasized that 1972 dollars were used throughout the study unless otherwise specified.

The components of the STOL transportation system were tested against pertinent criteria to assess whether the system would be environmentally acceptable to the airport neighborhoods, could reduce congestion at the major

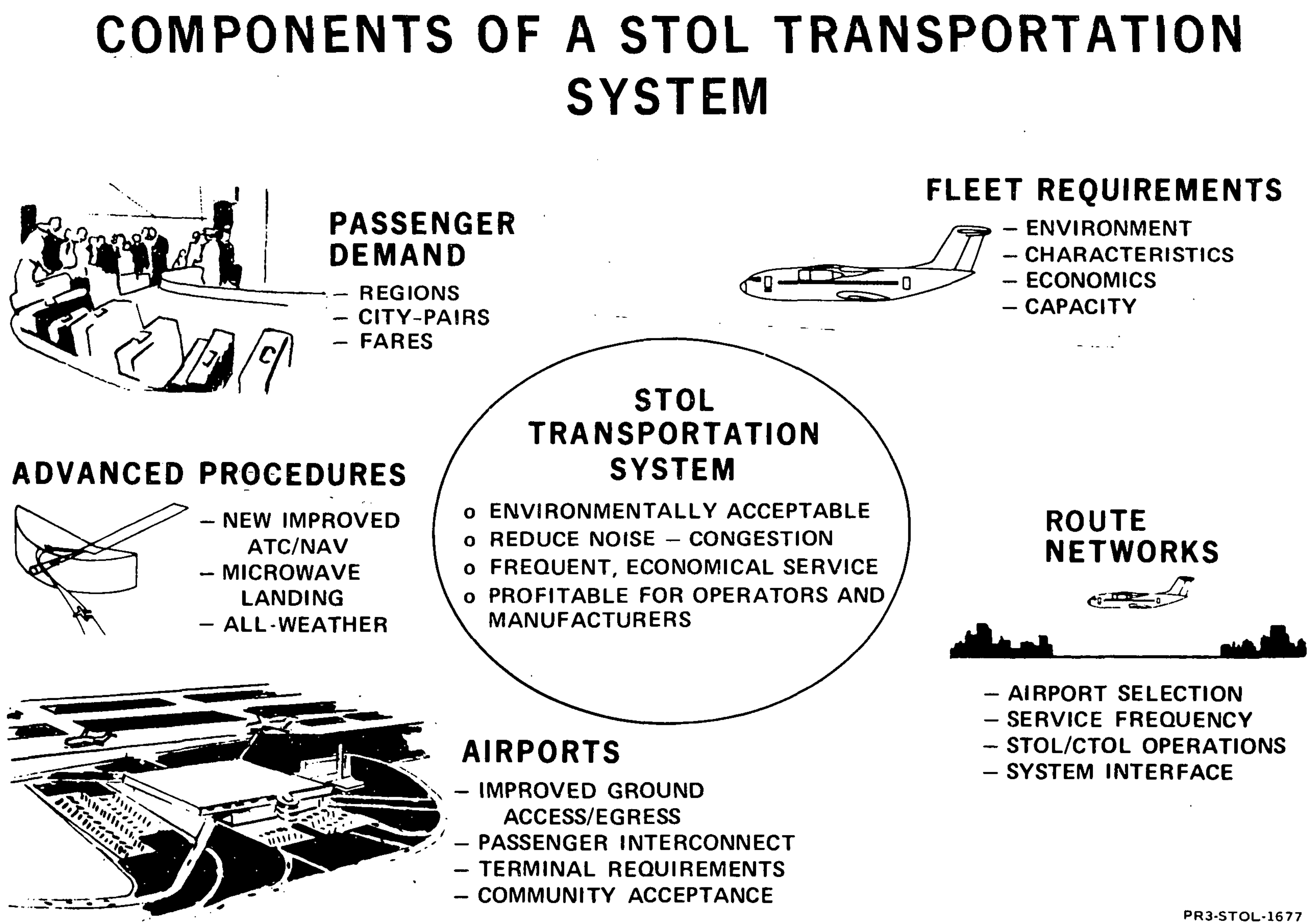
COMPONENTS OF A STOL TRANSPORTATION SYSTEM
PASSENGER DEMAND
– REGIONS
– CITY-PAIRS
– FARES
FLEET REQUIREMENTS
– ENVIRONMENT
– CHARACTERISTICS
– ECONOMICS
– CAPACITY
STOL TRANSPORTATION SYSTEM
o ENVIRONMENTALLY ACCEPTABLE
o REDUCE NOISE – CONGESTION
o FREQUENT, ECONOMICAL SERVICE
o PROFITABLE FOR OPERATORS AND MANUFACTURERS
ADVANCED PROCEDURES
– NEW IMPROVED ATC/NAV
– MICROWAVE LANDING
– ALL-WEATHER
ROUTE NETWORKS
– AIRPORT SELECTION
– SERVICE FREQUENCY
– STOL/CTOL OPERATIONS
– SYSTEM INTERFACE
AIRPORTS
– IMPROVED GROUND ACCESS/EGRESS
– PASSENGER INTERCONNECT
– TERMINAL REQUIREMENTS
– COMMUNITY ACCEPTANCE
PR3-STOL-1677

FIGURE 4

hub airports, provide frequent and economical service to the travelers and be profitable for the operators and manufacturers.

SYMBOLS AND ABBREVIATIONS

APKM	Airplane Kilometer
APSM	Airplane Statute Mile
ASKM	Available Seat Kilometer
ASSM	Available Seat Statute Mile
ATA	Air Transport Association
AW	Augmentor Wing
BPR	Bypass Ratio
CTOL	Conventional Takeoff and Landing
DOC	Direct Operating Cost
DOT	Department of Transportation
EBF	Externally Blown Flap
FAA	Federal Aviation Administration
FPR	Fan Pressure Ratio
IBF	Internally Blown Flap
IOC	Indirect Operating Cost
MF	Mechanical Flap
MLS	Microwave Landing System
NASA	National Aeronautics and Space Administration
OW	Over-the-Wing (Also referred to as upper surface blowing)
O&D	Origin and Destination
QCSEE	Quiet, Clean STOL Experimental Engine
ROI	Return on Investment
STOL	Short Takeoff and Landing
TOC	Total Operating Cost
TOGW	Takeoff Gross Weight
USB	Upper Surface Blowing

Airplane Designations

Frequently, in this and other volumes of the report, the following designations are used to denote study aircraft.

E	. 150	.3000	.70
	Passenger Payload	Field Length (Ft)	Cruise Mach Number

E = EBF

I = IBF

A = AW

U = USB

M = MF

C = Advanced CTOL

1.0 STOL AIRCRAFT MARKETS

The principal source of city pair traffic data is the "Origin-Destination Survey of Airline Passenger Traffic" which is compiled by the Civil Aeronatuics Board (CAB). This publication provides information on traffic carried by certificated scheduled air carriers. The California Public Utilities Commission provided data on intra-state traffic in California. Passenger traffic for the CAB's top 1,000 city pairs was forecast to 1985 using a Douglas computer program. Almost all of these city pairs were above 50,000 annual origin-destination passengers by 1985. A total of 494 city pairs was identified as potential STOL markets. These city pairs met the selection criteria. These criteria required that city pairs be within 0 and 600 statute miles apart and generate 50,000 annual passengers by 1985.

These city pairs were categorized by distance and annual passenger volume to determine the markets with the best potential for the development of STOL service. Traffic between these city pairs (1970) represents 15 percent of the U.S. passenger miles/kilometers and 41 percent of the passengers.

In order to assure a broad representation of the U.S. market and in order to conduct the tradeoffs necessary to optimize system operations, a total of 319 city pairs and 7 representative regions were selected for detailed study. Higher density city pairs were also distinguished from lower density city pairs. The criteria established for higher density city pairs provided that they should generate 300,000 annual passengers by 1985 and be within 0 and 600 statute miles apart. A total of 96 high density city pairs was identified. Lower density city pairs were required to produce 50,000 or more annual origin-destination passengers by the year 1985.

These 7 networks were identified as the Northeast, California, Chicago, Southeast, Southern, Northwest, and Hawaii regions. All of the city pairs contained in these regions were under 600 statute miles (966 km) and are expected to generate 50,000 or more annual origin-destination air passengers by the year 1985. These 319 city pairs are expected to generate a total of 124 million origin-destination air passengers during the year 1985.

This represents 87 percent of the 142 million origin-destination air passengers expected to travel between the 494 city pairs in 1985. The great majority of the higher density city pairs have been included in the seven representative regions. Both in number of city pairs and number of passengers the seven regional networks constitute a representative statistical sample.

Examination of higher density city pairs where it might be possible to utilize STOL service led to the identification of 96 candidate city-pairs. These city-pairs were used to determine the market demand for 150 passenger STOL aircraft (baseline size) for stage lengths of 600 statute miles or less (966 km). Figure 1-1 depicts the STOL aircraft market study flow.

Figure 1-2 contains the forecast 1985 origin-destination traffic volume for all U.S. short haul city pairs, the seven representative regions, and the 96 high density city pairs. It is significant to note that over 90 million passengers are forecast to travel to and from these 96 city pairs by 1985. These passengers represent over 60 percent of the overall volume of passengers forecast to travel between all 494 short haul city pairs between 0 and 600 statute miles.

MARKETS - STUDY FLOW

CITY PAIR AND TRAFFIC SPLIT ANALYSIS

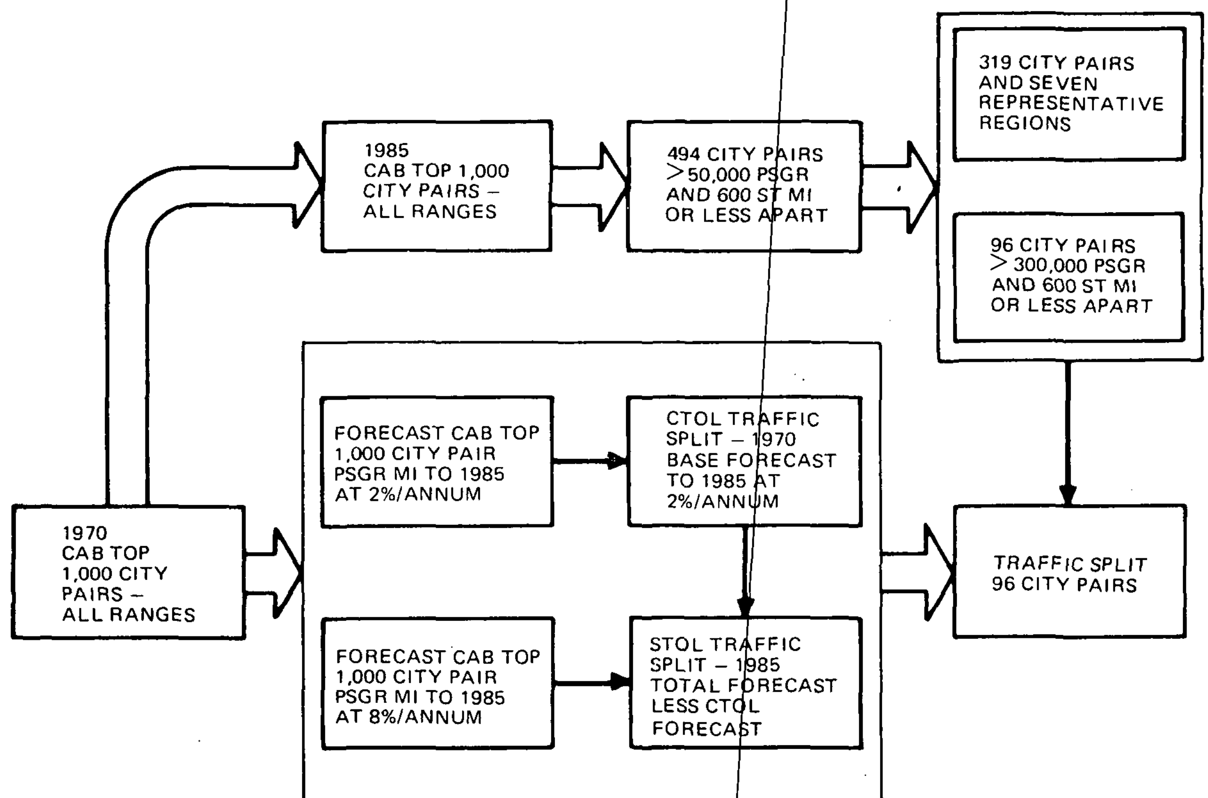

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FIGURE 1-1.

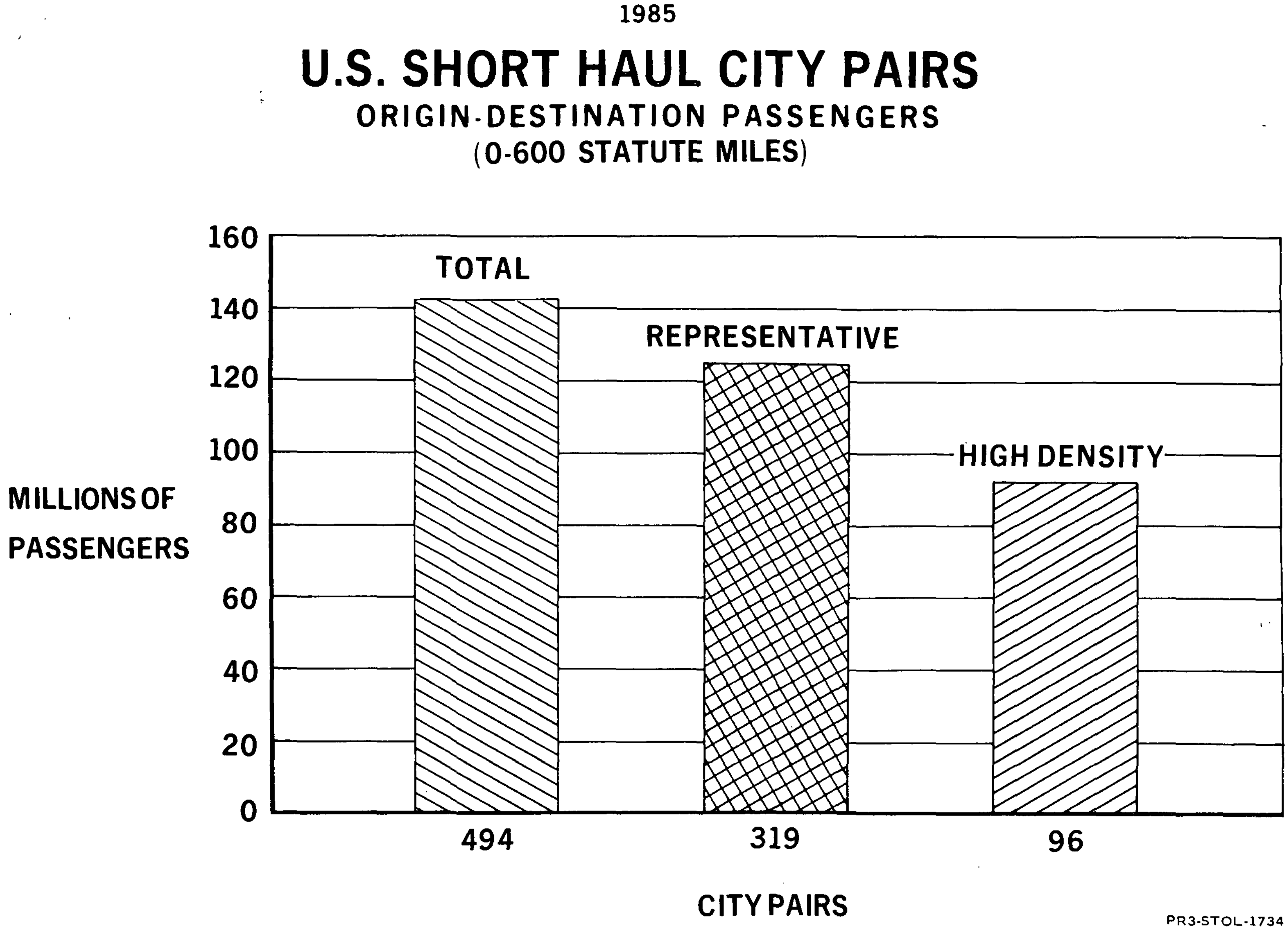

1985
U.S. SHORT HAUL CITY PAIRS
ORIGIN-DESTINATION PASSENGERS
(0-600 STATUTE MILES)
MILLIONS OF
PASSENGERS
160
140
120
100
80
60
40
20
0
TOTAL
REPRESENTATIVE
HIGH DENSITY
494
319
96
CITY PAIRS
PR3-STOL-1734

FIGURE 1-2.

1.1 Short-Haul Regions

In Phase I of this study, it was specified that the Contractor should conduct ". . . parametric systems analyses of a number of different STOL transportation systems in representative regions of the U.S. and develop the approach for analyzing total systems requirements in Phase II." Three representative regions (California, Northeast, Chicago) were developed using a total of 23 city pairs. Both high and low density city pairs were used to construct these representative regions. In addition, the city pairs selected were drawn from a mix of range categories.

In order to assure broader representation of the U.S. market and to conduct the tradeoffs necessary to optimize system operations, the three Phase I regions were expanded and four additional regions (Southern, Southeast, Northwest, Hawaii) were formulated for Phase II analysis. A total of 319 city pairs was examined in the seven regions. The information generated in this expanded analysis was also used to help define the national demand for STOL service.

1.1.1 Representative - Phase I - Three representative short haul market regions were studied during Phase I. These regions are identified by the crosshatched area in Figure 1-3. The city pairs selected for each representative region were modified from those shown in Figure 1-3. The airline subcontractors assisted Douglas in the development of these networks.

1.1.2 National - Phase II - During Phase II the three representative regions were expanded by the inclusion of additional city pairs. Four additional representative regions were added for Phase II analysis. Figure 1-4 depicts the passenger demand for these seven representative regions.

REPRESENTATIVE SHORT-HAUL MARKET REGIONS

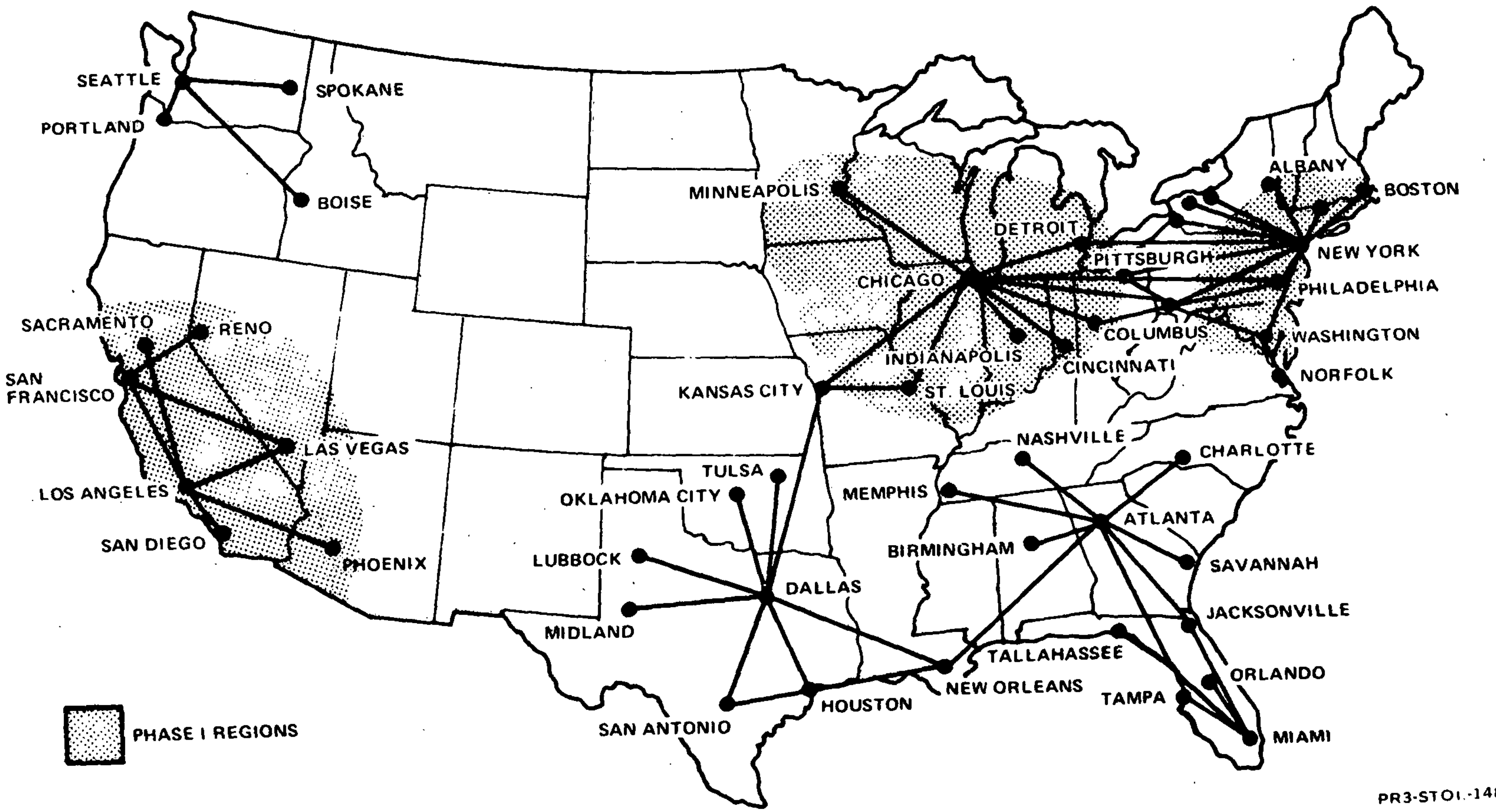


FIGURE 1-3

1985

REPRESENTATIVE SHORT HAUL MARKET REGIONS

ORIGIN-DESTINATION PASSENGERS
(0-600 STATUTE MILES)

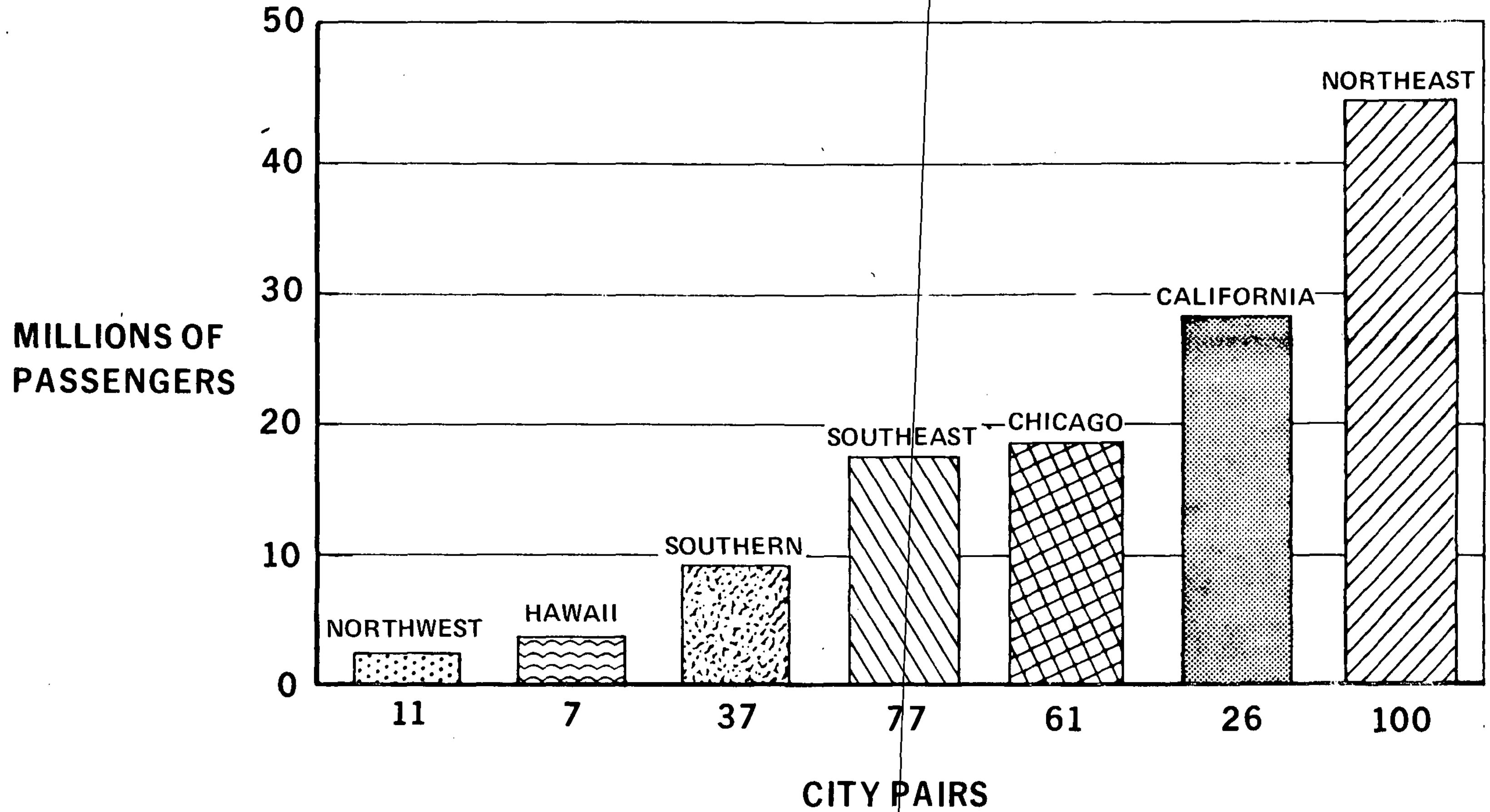


FIGURE 1-4.

A total of 124 million origin-destination passengers is expected to travel between the 319 city pairs constituting the 7 representative regions by 1985. Over one-third or almost 45 million of these passengers are expected to travel between the 100 city pairs which comprise the Northeast region. The California region is second to the Northeast region in passenger volume. This region accounts for over 28 million passengers and 26 city pairs. It also represents over 20 percent of total passenger volume in the 7 representative regions. One city pair, Los Angeles-San Francisco, is responsible for almost one-half of the passenger volume of the California region.

The Chicago region contains 61 city pairs and 15 percent of the total 1985 passenger volume. Seventy seven city pairs are contained in the Southeast region. These city pairs have lower passenger densities than those in the Chicago region. Over 17 million passengers are expected to travel to and from these city pairs in 1985.

The Southern, Northwest, and Hawaii regions, as a group account for almost 15 million passengers. This constitutes 12 percent of forecast short haul passenger movements between the 319 representative city pairs.

1.2 National Demand for STOL Aircraft

Prior to determining the national demand for STOL service and related aircraft, it was necessary to prepare a traffic forecast, select city pairs, and derive a modal split procedure. Stage lengths of from zero to 600 statute miles (966 km), in 100 statute mile (160 km) increments, were selected for the purpose of calculating the baseline demand for STOL aircraft.

A target load factor of 60 percent was used in the study. This load factor was used to convert forecast passenger miles into seat miles. The STOL 1985 market demand was calculated using the modal split procedure described in Section 4.0, Volume IV. The STOL passenger mile demand for the 0-600 statute mile (966 km) range category is 16.2 billion (26.1 billion passenger km). At a 60 percent load factor this converts to 27 billion seat miles (43.4 billion seat km). This analysis indicates there is a potential base market for 240 STOL aircraft (150 passengers) in 1985 based on the high-density city-pairs.

The STOL passenger mile demand was based on city pairs with an annual origin-destination passenger density of 300,000 or above. These are defined in this study as high-density city-pairs.

The U.S. domestic market for the baseline STOL for the year 1990 is estimated to be 320 aircraft. The traffic growth rates are consistent with those in the official annual Douglas publication, "Passenger Air Transport Market." See Volume II - Markets.

The sensitivity of the baseline market to different modal split assumptions was examined using the following procedure. The 1970 level of short haul CTOL traffic for U.S. city pairs was forecast to 1985. The growth rate from 1970 to 1985 was 8 percent compounded annually. In order to maintain the viability of the present CTOL system, both with respect to connecting and origin-destination passengers, the 1970 level of origin-destination passengers was assigned to CTOL aircraft. In addition, this 1970 CTOL base was allowed to expand by 2 percent a year reflecting the fact that not all U.S. city pairs are affected by airside and groundside congestion. The STOL

modal split consists of 75 percent of the U.S. short-haul market growth of 8 percent per year between 1970 and 1985 or 6 percent per annum.

A high STOL market estimate was prepared for both 1985 and 1990 by allocating all of the traffic growth of 8 percent per annum to the STOL system. A low STOL market estimate was prepared by allowing the 1970 base level of CTOL short-haul traffic to expand by 4 percent per annum. The STOL market was permitted to expand by the same rate thus reducing the number of STOL aircraft required. These estimates are shown in Table 1-1.

Table 1-1

U.S. CIVIL MARKET FOR 150 PASSENGER STOL AIRCRAFT

(96 HIGH DENSITY CITY PAIRS)

YEAR	MARKET ESTIMATE	0-600 s mi 0-966 km
1985	HIGH	290
	BASE	240
	LOW	175
1990	HIGH	420
	BASE	320
	LOW	235

1.3 Foreign and Military Markets

In order to determine potential STOL aircraft production levels, it is necessary not only to define the national demand for STOL service, but also to estimate foreign markets and possible military sales. Selection of city pairs to determine the foreign market for STOL aircraft followed the approach used for U.S. city pairs to the extent possible considering data

availability. Possible U.S. military sales of STOL vehicles were also estimated. Potential commonality between military programs and the commercial program was then estimated and higher quantity runs were used for common components and assemblies when computing commercial STOL aircraft unit costs.

1.3.1 Foreign Civil Markets - The procedure for estimating the non-U.S. market for STOL aircraft was similar to that used for the United States. However, there is far less data available on foreign civil markets. For example, the U.S. Civil Aeronautics Board publishes detailed origin-destination passengers statistics that are not available elsewhere in the world. However, where possible, as in the case of the modal or traffic split analysis, a similar analytical approach was adopted.

1.3.1.1 Selection of City Pairs - Detailed passenger traffic is not available for all foreign city pairs although seats flown between any city pair can be determined. Therefore, seats flown were used rather than passengers to estimate the traffic density.

Using an existing computer program, the foreign city pairs with a potential for STOL service were determined by using the Official Airline Guide (OAG) tapes.

This was done for range increments from 0-600 statute miles (0-966 km). There were 200 city pairs which resulted from this procedure. These city pairs are contained in Appendix 11.8, Volume IV.

1.3.1.2 Modal Split Analysis - The annual Douglas "Passenger Air Transport Market" publication projects a foreign traffic growth rate of 9.6 percent between 1971 and 1985. A literature survey and a review of Douglas experience

indicates that air and ground congestion is not projected to be as severe in most areas of the world as it is in the U.S. For this reason, the 1971 level of passenger traffic for the range categories of interest was assigned to CTOL and allowed to expand at a rate of 4 percent per annum. The remainder of the growth or 5.6 percent per annum was assigned to STOL. A similar procedure was followed to estimate the non-U.S. STOL aircraft market for the year 1990. In this instance, the forecast traffic growth rate between 1971 and 1990 was 9.2 percent. After allocating 4 percentage points to provide for continued CTOL growth, the remaining 5.2 percent was assigned to STOL.

1.3.1.3 Foreign STOL Civil Market - The estimated foreign civil market for 150 passenger STOL aircraft is shown below.

FOREIGN CIVIL MARKET FOR 150 PASSENGER STOL AIRCRAFT

(HIGH DENSITY CITY PAIRS)

YEAR	0-600 s mi 0-966 km
1985	320
1990	545

It should be noted that these figures represent the base case. Sensitivity variations from this base case have been developed to depict the upper and lower market demand boundaries.

The upper or high STOL market demand boundary was developed by holding assumed CTOL growth to a rate of two percent per annum as opposed to four percent per annum in the base case. The remainder of the growth, in the case of the 1985 forecast, or 7.6 percent was assigned to STOL. A lower STOL

market demand boundary was created by postulating a CTOL growth rate of six percent per annum. As before, the remainder of the growth was allocated to STOL. Table 1-2 shows the high, base and low cases for the years 1985 and 1990.

Table 1-2

FOREIGN CIVIL MARKET FOR 150 PASSENGER STOL AIRCRAFT

YEAR	MARKET ESTIMATE	0-600 s mi 0-966 km
1985	HIGH	390
	BASE	320
	LOW	230
1990	HIGH	655
	BASE	545
	LOW	390

1.3.2 Military Markets - There is no military market for commercial STOL aircraft. In view of the specialized military requirements for the STOL mission and the unique commercial requirements for safety, economy and low community noise, there is no military market foreseen for off-the-shelf civil STOL aircraft. There are significant commonality benefits which apply to both military and commercial designs in the propulsion, wing, and operating sub-systems which will reduce the overall program cost. This is discussed in more detail in Section 9.0.

SUMMARY

The analysis presented in this section (STOL Aircraft Markets) is based on the high-density city-pairs which form the structure of the regional systems. The STOL market for the representative national system, which

includes the high-, medium-, and lower-density city-pairs, is contained in Section 6.0 Systems Analysis.

WORLD CIVIL BASELINE MARKET (HIGH DENSITY CITY PAIRS)

(Based on 150 Passenger Aircraft Operating on Stage Lengths Up to 600 St. Mi.)

YEAR	U.S.	FOREIGN	TOTAL
1985	240	320	560
1990	320	545	865

For the purpose of economic studies, it was assumed that the world market estimate of 865 aircraft by 1990 would be approximately divided between two aircraft manufacturers. Therefore, development and manufacturing costs of airframes, engines and subsystems were calculated and analyzed throughout the study based on a production quantity of 400 airplanes for one manufacturer.

2.0 REPRESENTATIVE AIRCRAFT CONFIGURATIONS

2.1 Aircraft Analysis Study Plan

The procedure used to derive and analyze aircraft configurations for the study is shown in Figure 2-1. Preliminary basepoint designs were laid out for each lift concept and analyzed in detail for weights, aerodynamic and propulsion characteristics, and acoustics. The purpose of these preliminary basepoint designs was to assure design realism in the aircraft configurations. To help assure this realism four airline subcontractors (Air California, Allegheny, American and United) assisted in evaluating the configuration arrangements. Engines for each of the lift concepts were selected from the matrix of QCSEE Task I parametric engines for both contractors (Detroit Diesel Allison and General Electric).

Based on these preliminary basepoint designs over 200 parametric aircraft were generated and selected through an iterative process using evaluation criteria such as DOC, wing loading and thrust loading, gross weight and other configuration parameters. Eight of these selected aircraft were then studied in detail through the systems analysis process (markets, airports, economics and systems operations).

Concurrently trade studies were conducted on these eight aircraft and significant results incorporated in the final set of eight aircraft designs (final design aircraft) which are substantiated in detail in the Aircraft Report. Critical technology necessary to implement the STOL short haul system in response to the study objectives were also determined and are summarized later in Section 8.0.

AIRCRAFT ANALYSIS STUDY PLAN

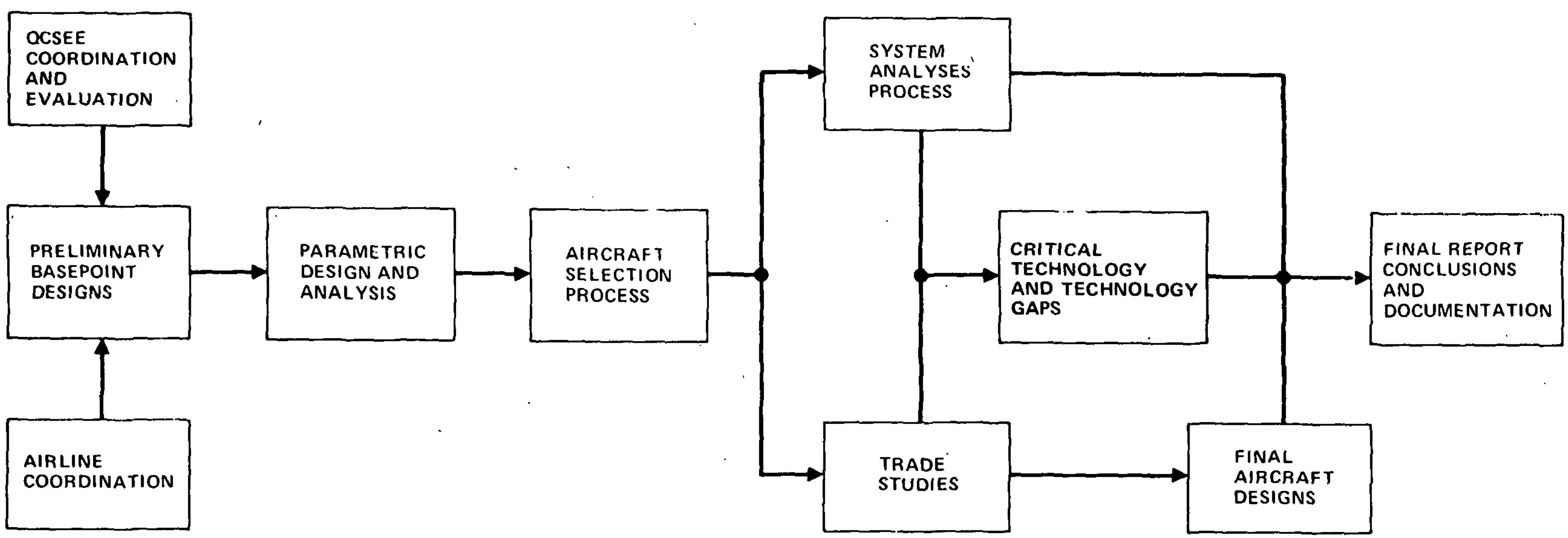


FIGURE 2-1.

PR3-STOL-1762 A

2.1.1 Aircraft Study Matrix. - The design lift concepts for this study are shown in Figure 2-2 including the design parameters which sized the aircraft. THe passenger capacities for the parametric aircraft (Phase I) varied from 50 to 200 passengers. The 50 passenger designs were eliminated for Phase II because they were too small for the market and their direct operating costs were excessively high. In a similar manner, the design field lengths were changed from 1500 - 3000 feet (457 - 914 m) to 2000 - 4000 feet (610 - 1219 m) between Phase I and Phase II because of the poor economics associated with the very short field length and the need to study the mechanical flap design at a longer field length. The airframes and engines were sized for the STOL mission with the cruise Mach number resulting primarily from the thrust level required to meet the short field performance. Economic studies showed that the cruise Mach number had little impact upon the total system economics for the short haul stage lengths which justified this approach. The design range in all cases was 575 statute miles (925 km). The design noise level for the Phase I parametric aircraft was 95 PNdB at 500 feet (152 m) sideline distance. The systems analysis aircraft of Phase II (discussed previously) were designed to 95 EPNdB at 500 feet (152 m) sideline distance. The design noise levels for the final design aircraft were relaxed slightly in order to achieve significantly better aircraft economics (sideline noise levels between 95 and 98 EPNdB).

2.2 Final Design Aircraft

Eight aircraft were selected from the parametric studies for detailed aircraft design and systems analysis. The design requirements and lift systems chosen for this detailed analysis are shown in Figure 3 of the Introduction.

AIRCRAFT STUDY MATRIX

DESIGN PARAMETERS	PARAMETRIC AIRCRAFT PHASE I	FINAL DESIGN AIRCRAFT PHASE II
PASSENGER CAPACITY	50, 100, 200	100, 150, 200
FIELD LENGTH FT (M)	1500, 2000, 3000 (457) (610) (914)	2000, 3000, 4000 (457) (610) (914)
CRUISE MACH NUMBER	VARIABLE	VARIABLE
DESIGN RANGE ST MI (KM)	575 (925)	575 (925)
NOISE (500 FT SIDELINE)	95 PNdB	95 TO 98 EPNdB
DESIGN CONCEPTS	EXTERNALLY BLOWN FLAP UPPER SURFACE BLOWING AUGMENTOR WING INTERNALLY BLOWN FLAP MECHANICAL FLAP	

FIGURE 2-2.

PR3-STOL-1795B

2.2.1 Final Design Aircraft Performance Summary. - A comparison of the characteristics of the eight final design aircraft is shown in Table 2-1.

The wing loadings for the 2000 foot (610 m) propulsive lift aircraft are low and would require ride quality augmentation. The mechanical flap aircraft for the 3000 foot (914 m) field length also has a low wing loading. The externally blown flap, augmentor wing and upper surface blowing aircraft for 3000 foot (914 m) field lengths have acceptable wing loadings.

The cruise speeds of the 3000 foot (914 m) externally blown flap designs are the lowest and are due to the thrust lapse of the very high bypass ratio engines. This is partially overcome in the 2000 foot (610 m) externally blown flap aircraft by its higher thrust-to-weight ratio. The mechanical flap aircraft also have relatively low cruise speeds. The augmentor wing has the highest cruise speed because of the very low bypass ratio engine and its low thrust lapse. The thrust-to-weight ratio of 0.361 for the augmentor wing aircraft is increased during the STOL mode to somewhat higher values by the augmentor system.

The sideline noise levels of these aircraft vary between 95 and 98 EPNdB as discussed earlier. The direct operating costs for the eight final design aircraft vary from 1.64 to 2.42 ¢/ASSM (1.02 to 1.50 ¢/ASKM). Direct operating cost is discussed in more detail in paragraph 5.1.4.

2.2.2 Final Design Aircraft Configurations. - The final design EBF, 150 passenger, 3000 foot (914 m) field length 3-view is shown in Figure 2-3. The propulsive lift concepts are high wing designs because of the adverse ground effects associated with the very high propulsive lift coefficients. T-tails are used throughout the designs because of the

TABLE 2-1

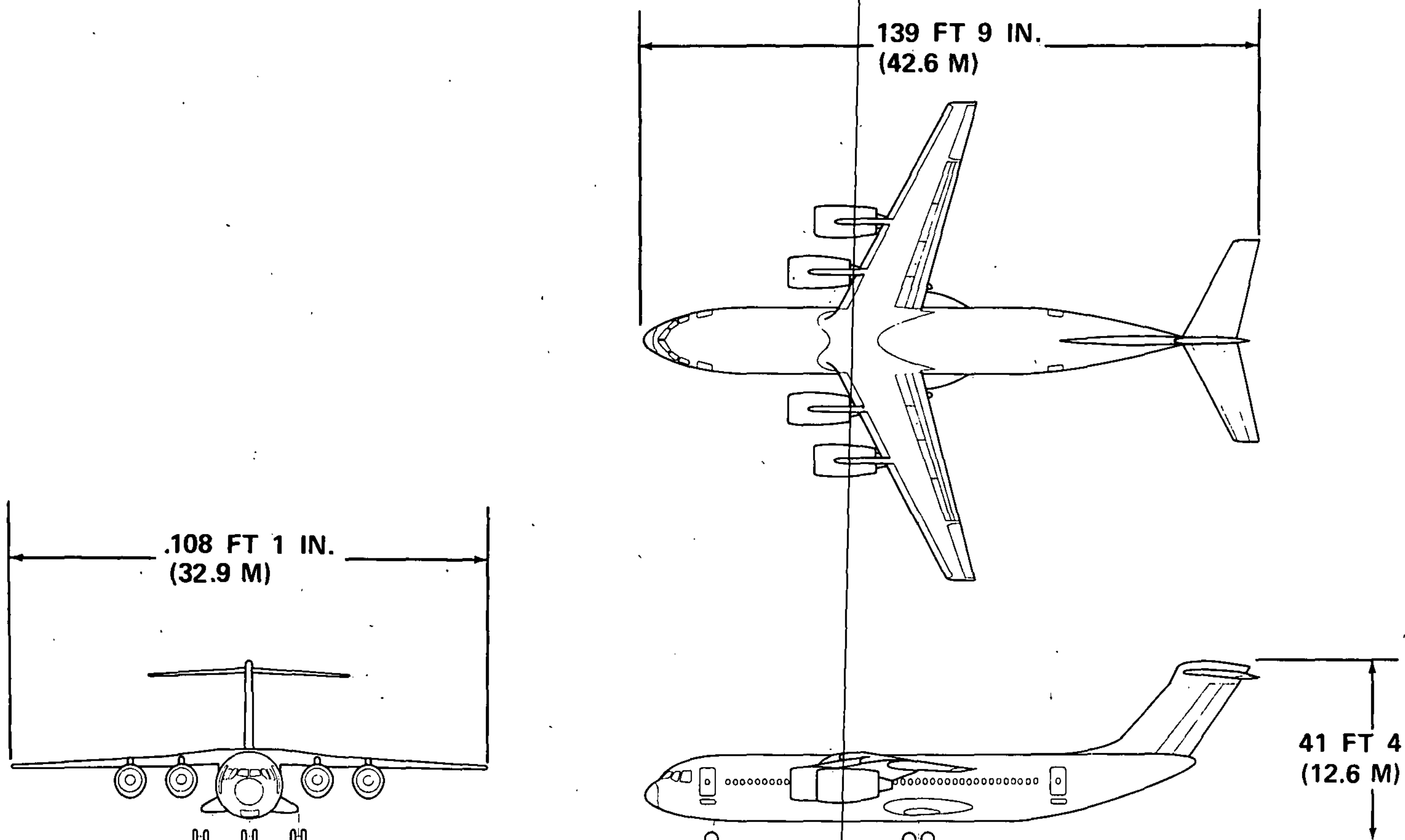
FINAL DESIGN AIRCRAFT PERFORMANCE SUMMARY

Configuration		EBF				MF		AW	USB
Passengers		100	150	200	150	150	150	150	150
Design Field Length	Ft (M)	3000 (914)	3000 (914)	3000 (914)	2000 (610)	3000 (914)	4000 (1220)	2000 (610)	2000 (610)
Engine		PD287-3	PD287-3	PD287-3	PD287-3	PD287-23	PD287-23	PD287-43	PD287-22
TOGW	Lb (Kg)	104,060 (47,200)	149,030 (67,600)	192,030 (87,100)	196,000 (88,900)	190,960 (86,620)	155,790 (70,660)	212,590 (96,430)	227,120 (103,020)
Wing Area	Ft^2 (M^2)	991 (92.1)	1461 (135.7)	1920 (178.4)	2800 (260.1)	3007 (279.4)	1708 (158.7)	2743 (254.8)	3390 (314.9)
Thrust/Engine	Lb (N)	13,200 (58,720)	18,260 (81,220)	22,920 (101,950)	25,830 (114,900)	36,990 (164,540)	32,450 (144,340)	19,200 (85,410)	29,490 (131,180)
Wing Loading	Lb/Ft^2 (Kg/M^2)	105.0 (512.7)	102.0 (498.0)	100.0 (488.2)	70.0 (341.8)	63.5 (310.0)	91.2 (445.3)	77.5 (378.4)	67.0 (327.1)
Thrust to Weight Ratio		0.508	0.490	0.478	0.527	0.387	0.417	0.361	0.519
Number of Engines		4	4	4	4	2	2	4	4
Aspect Ratio		8.0	8.0	8.0	8.0	9.0	9.0	6.5	8.0
Cruise Mach Number		0.69	0.69	0.69	0.74	0.70	0.72	0.78	0.76
Cruise Altitude	Ft (M)	25,000 (7620)	26,000 (7925)	26,000 (7925)	30,000 (9144)	28,000 (8534)	27,000 (8230)	30,000 (9144)	30,000 (9144)
Field Length	Ft (M)	3000 (914)	3000 (914)	3000 (914)	2000 (610)	3000 (914)	4000 (1220)	2000 (610)	1820 (555)
Approach Path Angle	Deg	5.5	5.5	5.5	7.1	5.4	4.5	7.3	7.1
Takeoff Climbout Angle	Deg	9.0	8.8	8.5	11.2	8.8	9.5	11.2	11.6
Noise (500 Ft. Sideline)	EPNdB	96	96	96	96	97	97	95	98
DOC at 575 St Mi	(¢/ASSM) (¢/ASKM)	2.33 1.45	1.88 1.17	1.64 1.02	2.26 1.40	2.08 1.29	1.77 1.10	2.35 1.46	2.42 1.50

FINAL DESIGN AIRCRAFT

EXTERNALLY BLOWN FLAP AIRCRAFT

150 PASSENGERS - 3000 FT (914 M) FIELD LENGTH



PR3-STOL-1512B

FIGURE 2-3

very high downwash gradients associated with these propulsive lift coefficients. The high lift system consists of large extension two-segment flaps. A set of spoilers is used for direct lift control, lateral control and ground spoiling. Wing leading edge devices consist of drooped leading edges in the vicinity of the engine pods and slats outboard. An inverted leading edge flap is also used on the horizontal tail to increase the stabilizer effectiveness.

Controls consist of conventional ailerons and outboard spoilers, an elevator and a double hinged rudder. The stability and control characteristics of the aircraft are considerably enhanced by the use of a 3-axis stability and control augmentation system (SCAS).

The engines shown are a variable pitch fan design with a bypass ratio of 17 and are placed below and ahead of the flap system. The thrust-to-weight ratio necessary to meet the STOL performance is approximately twice that of a CTOL aircraft. These latter two engine characteristics result in nacelles considerably larger than those of current CTOL aircraft.

The 2000 foot (610 m) field length, 150 passenger, USB aircraft is shown in Figure 2-4. A high wing design has been chosen, as in the case of the EBF configuration. The engines are placed ahead of the wing structure in order to facilitate engine removal and maintenance which was emphasized by the airline subcontractors. The high location of the engine will require additional ground equipment relative to the other propulsive lift concepts studied. The high location however should result in less foreign object damage. Shielding of the engine related noise by the wing, which is a primary consideration for the USB configuration, will result for the engine exhaust and some of the jet engine related noise. The engine inlet however will not

FINAL DESIGN AIRCRAFT

UPPER SURFACE BLOWN AIRCRAFT

150 PASSENGERS - 2000 FT (610 M) FIELD LENGTH

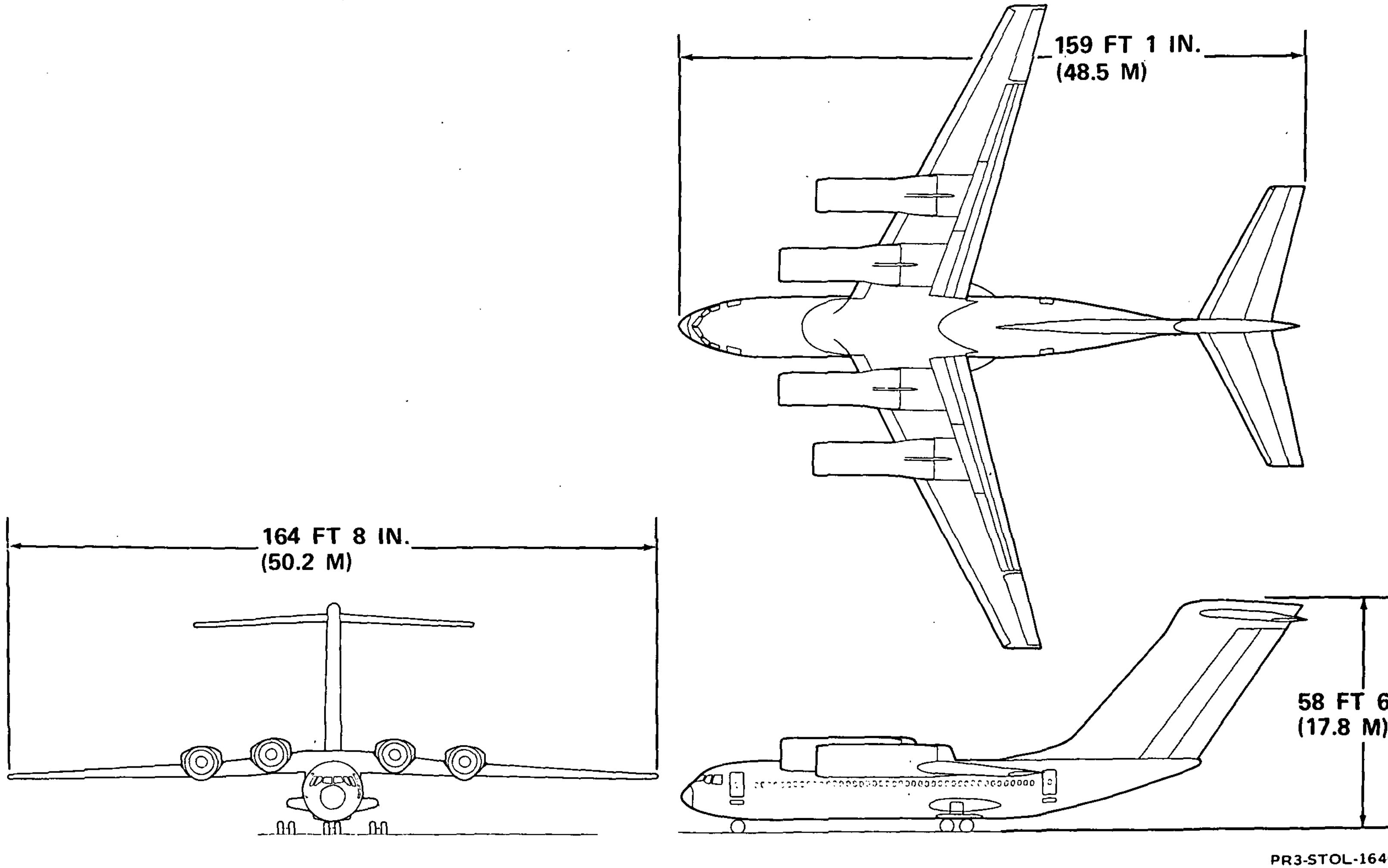


FIGURE 2-4

benefit from this high wing location and additional acoustic treatment may be necessary to treat the engine fan noise. The engines used for the USB design have a slightly higher fan pressure ratio than the EBF design to take advantage of the wing acoustic shielding. They are fixed pitch fan engines with a bypass ratio of 14.8 (fan pressure ratio 1.3).

The USB concept for 2000 foot (610 m) field length was the highest weight and DOC aircraft in the study. This resulted from a small loss in $C_{L_{max}}$ due to the proximity of the nacelle to the wing leading edge and to the installation weight of the engine.

The general arrangement for the 150 passenger, 2000 foot (610 m) field length augmentor wing aircraft does not differ greatly from the other propulsive lift designs except for the engine installation and details of the wing geometry (Figure 2-5). The engine installation and ducting system required for the AW is discussed in Volume II, Aircraft Report. The engines are of two-flow design and have a fan pressure ratio of 3.0. A sonic inlet is used to quiet this low bypass ratio (2.8) engine. The aspect ratio for the AW has been reduced to 6.5 to provide adequate area behind the rear spar for the augmentor ducting system.

The twin engine, mechanical flap designs have large wings (low wing loadings) as shown in Figure 2-6 for the 150 passenger, 3000 foot (914 m) field length aircraft. The low wing loading is necessary to offset the lack of propulsive lift and will require a development effort to achieve acceptable ride qualities. The high wing position is governed by engine ground clearance and foreign object damage considerations. An aspect ratio of 9 was selected based on the engine out performance characteristics of a two engine aircraft. Fixed-pitch fan engines are used with a fan pressure ratio of 1.5. Fan

FINAL DESIGN AIRCRAFT

AUGMENTOR WING AIRCRAFT

150 PASSENGERS - 2000 FT (610 M) FIELD LENGTH

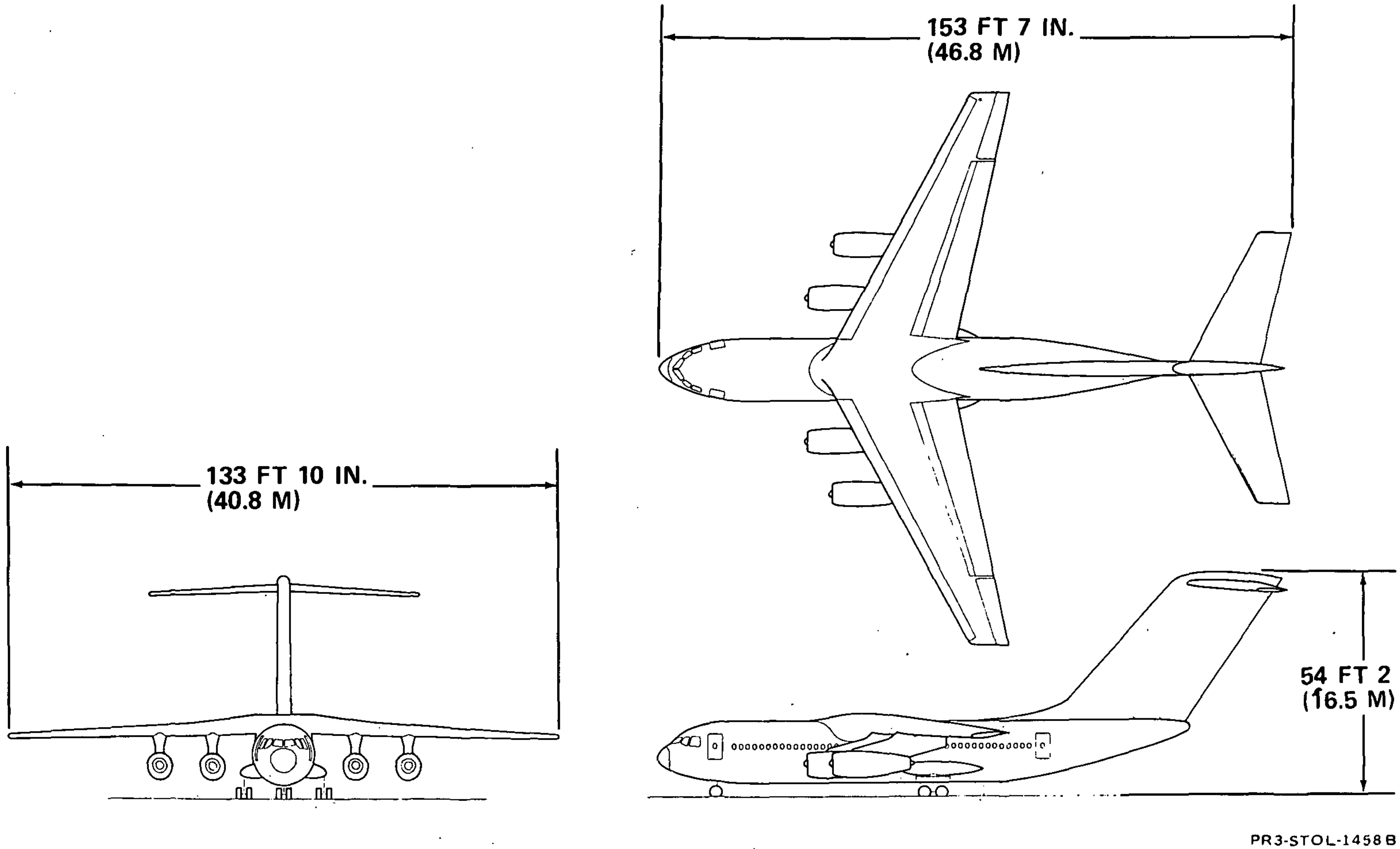


FIGURE 2-5

FINAL DESIGN AIRCRAFT

MECHANICAL FLAP AIRCRAFT

150 PASSENGERS • 3000 FT (914 M) FIELD LENGTH

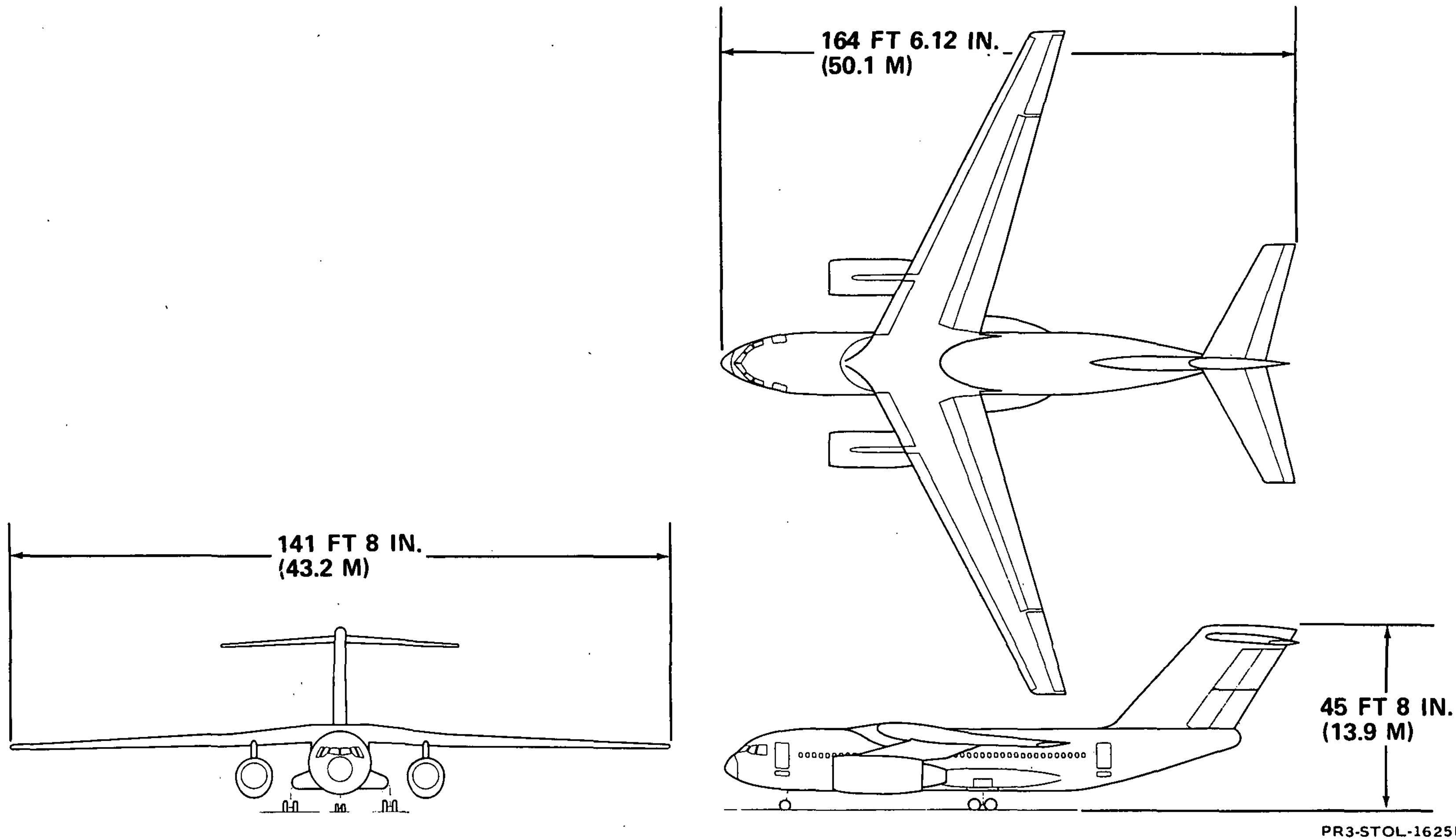


FIGURE 2-6

pressure ratio selection was influenced by the maximum diameter of eight feet which is the largest size that can be routinely shipped by road.

2.3 Trade Studies

The externally blown flap, 150 passenger, 3000 foot (914 m) field length aircraft was used as a baseline for extensive trade studies. Several of the most pertinent of these studies are summarized below.

Aircraft Noise Study - The acoustics tradeoff study used engines with fan pressure ratios of 1.25, 1.32, and 1.57 and three levels of acoustic treatment. The results showed that it was not cost effective to use rings for treatment since the acoustics wall treatment produced considerable reduction in noise with only minor increase in TOGW and DOC.

Propulsive lift noise for the EBF and USB designs constitutes a noise floor beyond which it is not economically feasible to suppress the engine noise sources. Figure 2-7 shows that large penalties result when acoustic rings are used in the fan inlet and exhause to suppress the fan noise below that of the EBF flap interaction noise. These penalties are large due to the impact of fan losses on engine performance. Based on this study the 500 foot (152 m) sideline noise of the final design EBF and USB aircraft are slightly greater than 95 EPNdB due to elimination of the fan ring treatment. The aircraft, however, exhibit significant reductions in TOGW and DOC (approximately 10 percent).

It should be emphasized that the trade study aircraft are separate and distinct from any of the final design aircraft. For example, in the final design EBF airplane, the engine cycle was slightly different than the acoustics study aircraft, the nacelle inlet length to height ratio was greater

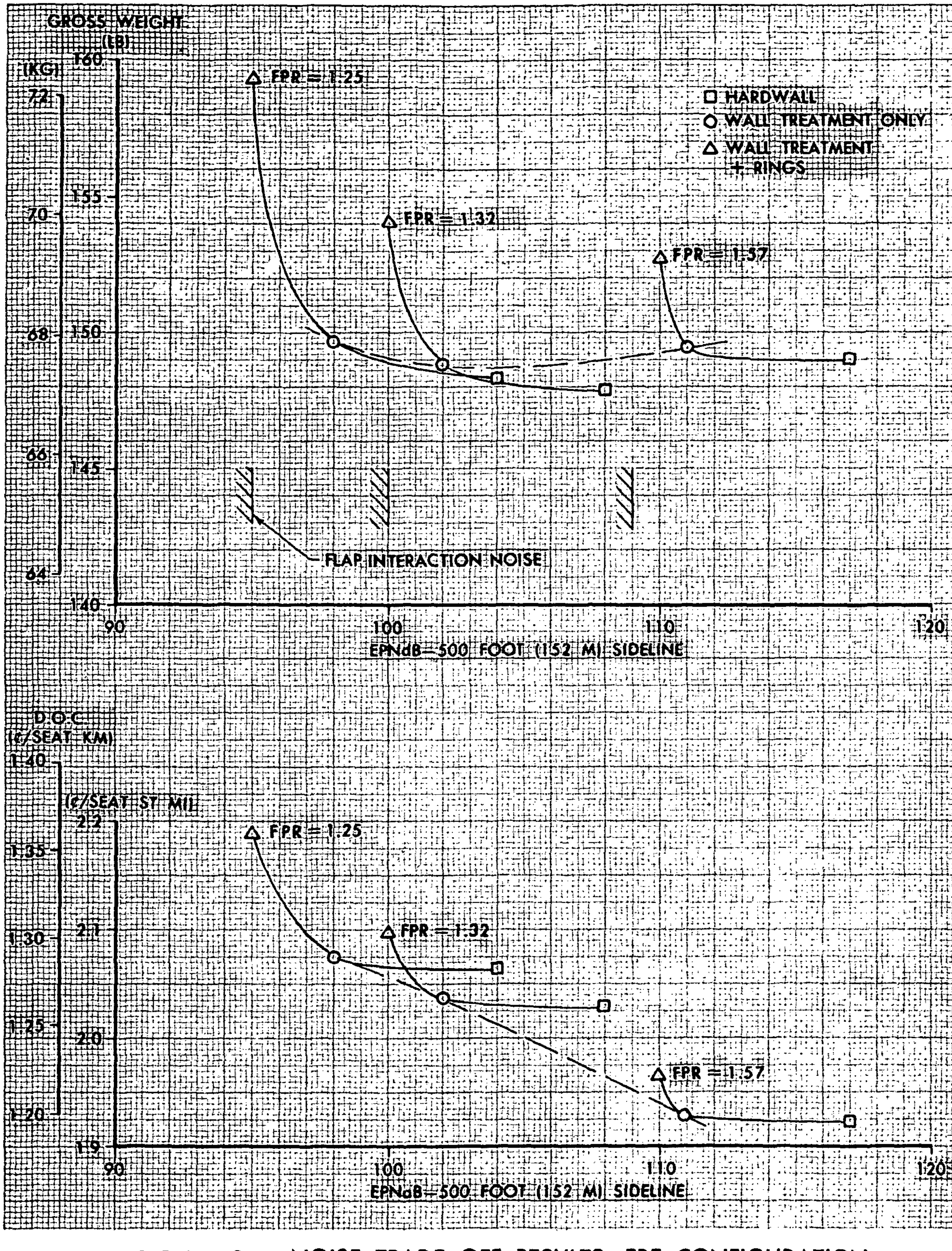


FIGURE 2-7. NOISE TRADE OFF RESULTS—EBF CONFIGURATION

as well as the amount of wall treatment. Thus the final design aircraft is 2 dB quieter than the trade study airplane. The final design EBF was then re-sized to reflect the various changes that were incorporated in the aircraft.

Configuration Studies - Many detailed configuration analyses were made in the derivation of the basic layouts of the aircraft. Some of these include the choice of aspect ratio (Figure 2-8) for the EBF baseline aircraft, choice of number of engines for the mechanical flap aircraft, detailed design of the various flap systems and mechanical aspects of the augmentor wing ducting system. The configurations shown in the study resulted from these and other detailed engineering considerations.

Performance Trade Offs - Performance optimization studies were conducted for each aircraft to determine optimum cruise altitude and cruise Mach number. Sensitivities were also derived to enable the user to evaluate other selected trade off considerations.

Landing Ground Rules - Because of the steep approaches, high touchdown sink rates and short field operations, the landing ground rules have a pronounced effect upon the choice of wing loading and thrust loading for a given aircraft. The rules were therefore studied relative to existing criteria and flight data acquired on aircraft such as the Breguet 941. It was concluded that a 900 foot/minute (274 m/min) approach with a flare to a 10 foot/second (3.28 m/s) touchdown velocity was reasonable for landing field length certification when used with the conventional 0.6 field length factor. These assumptions, however, need justification from a flight demonstration program.

Avionics - Avionic trade offs were conducted for several levels of avionics sophistication and related system capability. A cost and weight summary of these various levels of capability are summarized in Table 2-2.

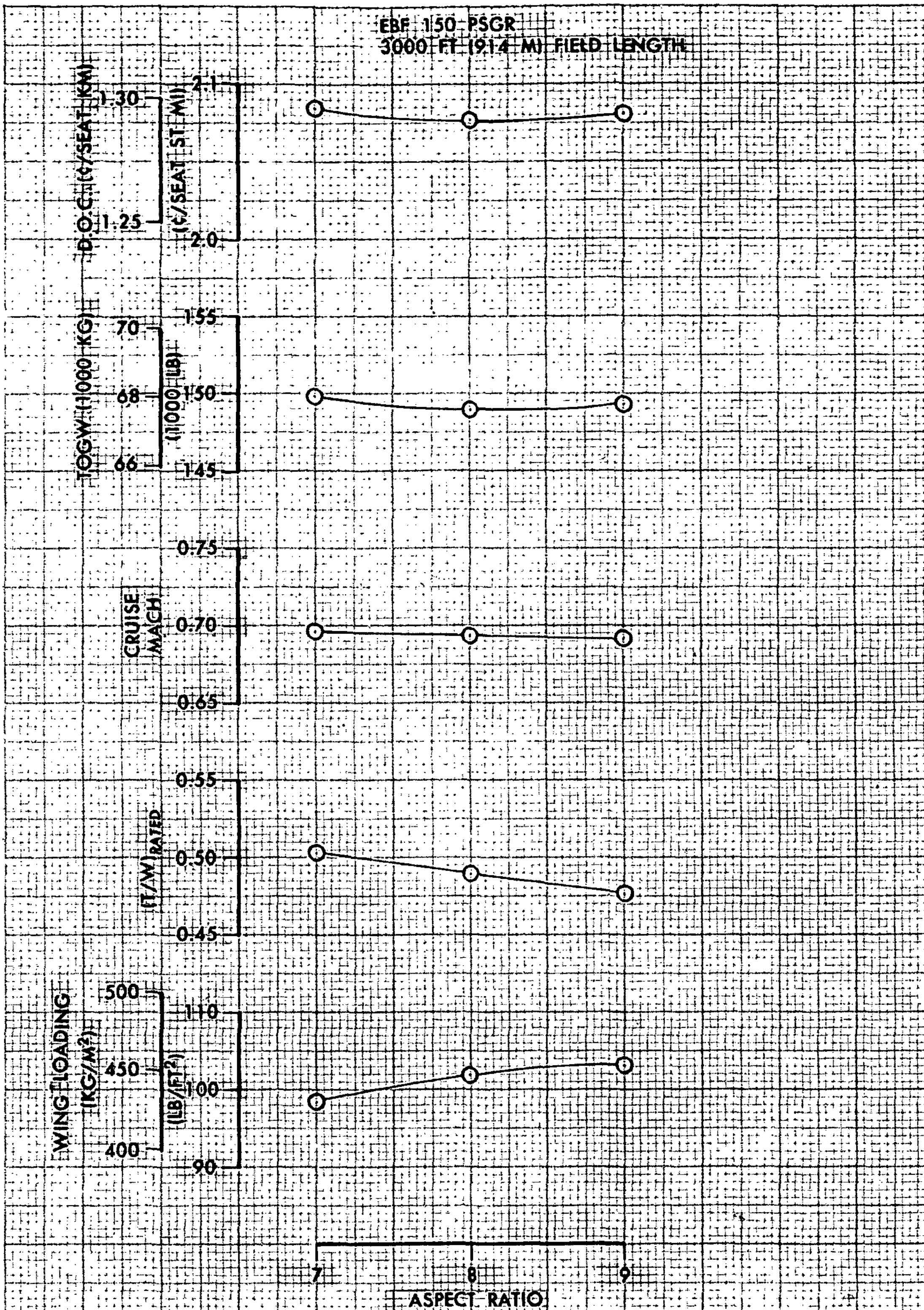


FIGURE 2-8. EFFECT OF ASPECT RATIO ON AIRCRAFT SIZING

Table 2-2

SUMMARY OF COST & WEIGHT SAVINGS FOR STOL AVIONICS

AVIONICS SUBSYSTEM	CAT III		CAT II		CAT I		CAT I (Less Weather Radar)	
	WEIGHT lb/kg	COST $	WEIGHT lb/kg	COST $	WEIGHT lb/kg	COST $	WEIGHT lb/kg	COST $
IFGCS*	702/316	386,707	661/298	311,707	610/274	291,707	610/274	291,707
Comm & Nav	665/299	140,583	646/291	132,507	507/228	104,093	457/205	82,093
Engine Insts & Misc Cockpit Insts.	159/ 72	43,945	159/ 72	43,945	159/ 72	43,945	159/ 72	43,945
TOTALS	1,526/687	571,235	1,466/661	488,159	1,276/574	439,745	1,225/551	417,745

*In-flight guidance and control system

Ride Qualities - Because of the low wing loadings required for many of the STOL aircraft, as related to field length, the critical problems in achieving acceptable ride qualities were studied. It was found that:

- Use of conventional elevator surfaces alone for improvement in longitudinal ride qualities for the approach mode does not appear to be very effective.
- Use of elevator and spoiler surfaces together are satisfactory in the approach mode, however, their use in cruise and transition flight regimes is not desirable and alternate solutions should be investigated.
- The use of rudder for lateral acceleration is unsatisfactory because the spiral mode and Dutch roll damping is reduced and the effectiveness is insufficient.

Design For Extended Range - Extended range for propulsive lift aircraft was investigated assuming that the design field length of 3000 feet (914 m) would be held constant at a range of 575 statute miles (925 km). Figure 2-9 shows the increased field length and decreased cruise Mach number resulting from the increase in gross weight as the range is extended. Aircraft with an extended range of 1400 statute miles (2250 km) would therefore have a field length of 3000 feet (914 m) at 575 statute miles (925 km) and 4100 feet (1250 m) at 1400 statute miles (2250 km). The cruise Mach number is lower at the extended range.

The corresponding increase in TOGW and DOC at the 575 statute mile (925 km) design range point is shown in Figure 2-10 to be less than one percent for the extended range designs. This nominal increase in weight results from a small increase in tankage and fuel system weight and a small increased allocation in passenger amenities.

PERFORMANCE AT EXTENDED RANGES

EXTERNALLY BLOWN FLAP - 150 PASSENGERS
MAINTAIN 3000 FT FIELD LENGTH AT STOL DESIGN RANGE = 575 ST MI

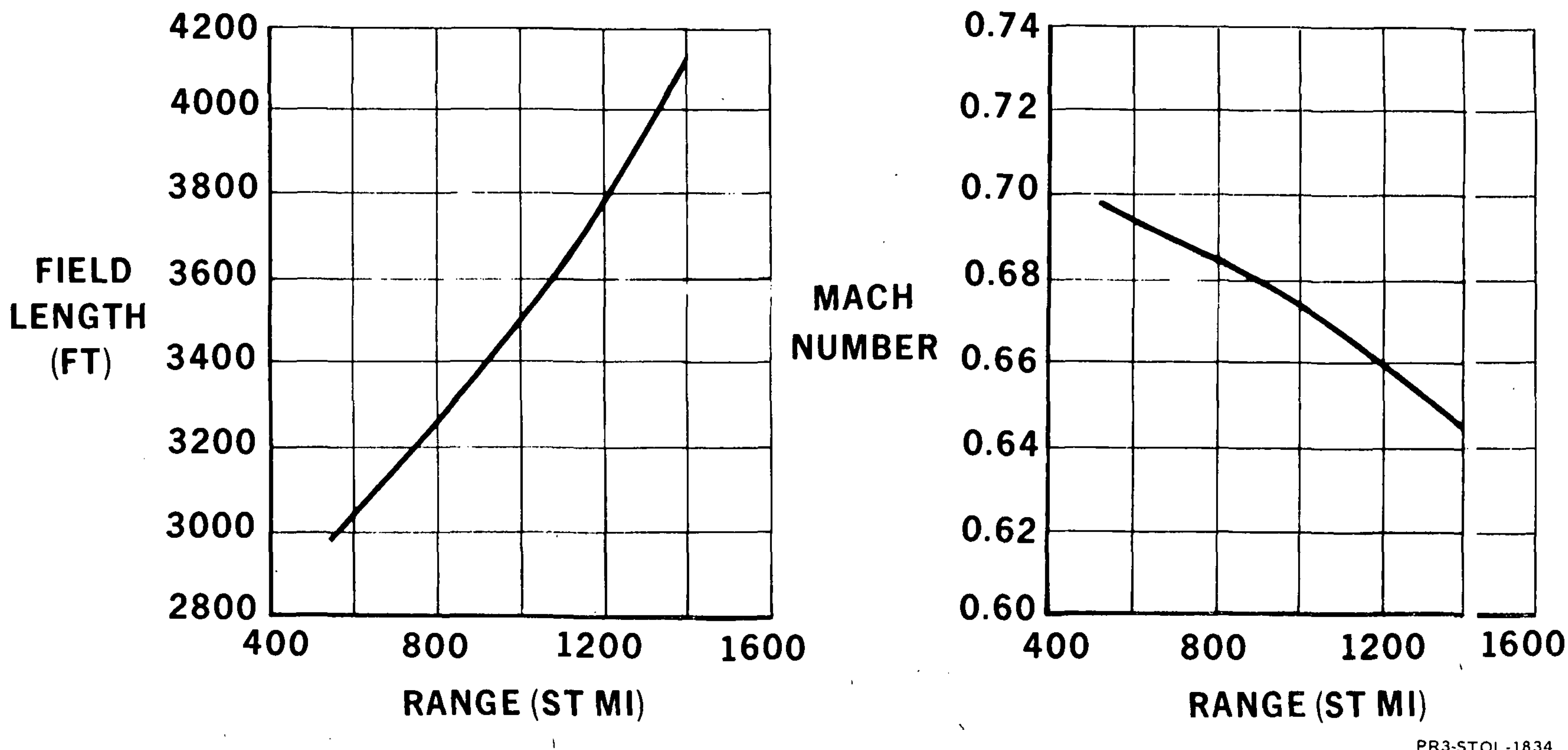


FIGURE 2-9.

PENALTY FOR EXTENDED RANGE CAPABILITY

EXTERNALLY BLOWN FLAP - 150 PASSENGERS
MAINTAIN 3000 FT FIELD LENGTH AT STOL DESIGN RANGE = 575 ST MI

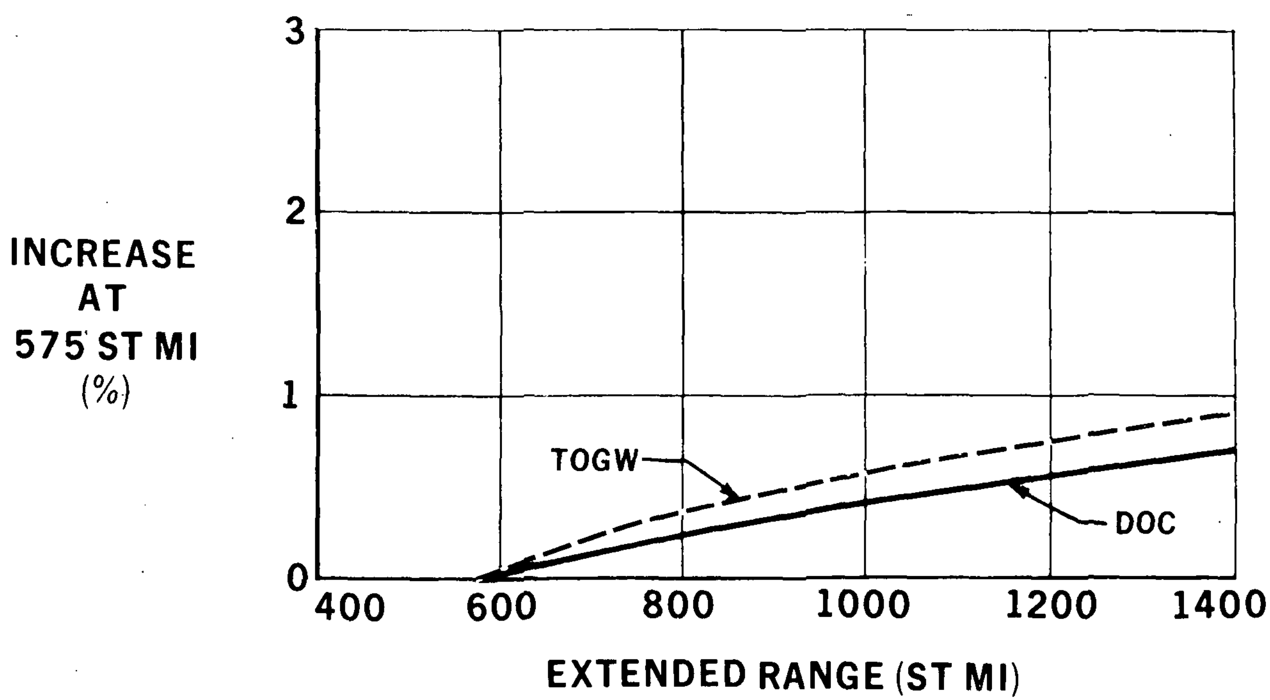


FIGURE 2-10.

PR3-STOL-1835

Because of the potential increase in operational flexibility and market value of the extended range aircraft, there are benefits in designing the short haul aircraft for this additional capability.

Application of Advanced Composites to STOL Aircraft - An auxiliary study to the basic program involved the investigation of costs and benefits of applications of advanced composites to civil STOL aircraft structures. The study integrates structural design, manufacturing development, and economic analysis to assure designs that are realistic from a production point of view and that are economically viable. A principal goal of the study is to assist in development of guidelines for application of advanced composites to primary STOL aircraft structure. The study is still in progress so that final cost data are not yet available.

Weight and cost analyses are based on design of the components shown in Figure 2-11. Emphasis of the study is to primary structure, shown by the shaded area. Basic composite material is graphite epoxy, used primarily in sandwich construction with aluminum honeycomb. Choice was based on cost and weight studies. Aluminum was chosen for the leading edge surfaces and tips because of lightning protection and rain erosion requirements. Aluminum ailerons and spoilers were selected based on cost and weight. The floor shown was developed based on weight-cost performance compared to available composite floor systems. Joining is by bonding, but mechanical attachments, both with and without bonding, are used for major load transfer areas and final assembly.

The resized composite structure aircraft is compared to the conventional metal baseline aircraft in Figure 2-12. The takeoff gross weight

COMPOSITE APPLICATION TO STOL FINAL DESIGN

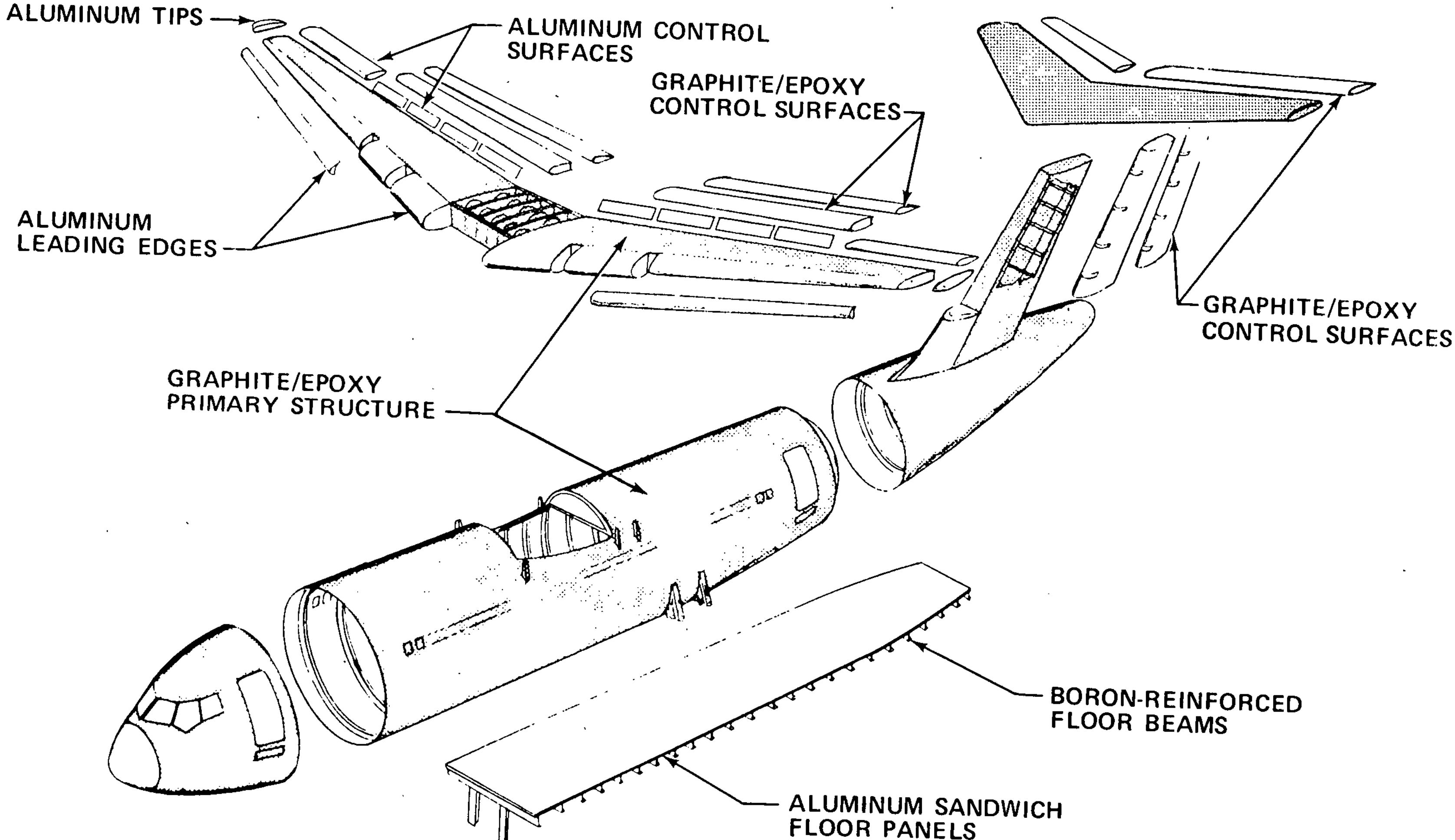


FIGURE 2-11

ADVANCED MATERIALS AIRCRAFT SUMMARY

EXTERNALLY BLOWN FLAP CONFIGURATION

		CONVENTIONAL STRUCTURE	COMPOSITE STRUCTURE
PASSENGERS		150	150
DESIGN FIELD LENGTH	FT (M)	3,000 (914)	3,000 (914)
TOGW	LB (KG)	149,030 (67,600)	132,300 (60,000)
WING AREA	SQ FT (SQ M)	1,461 (136)	1,285 (119)
RATED THRUST/ENGINE	LB (N)	18,260 (81,220)	16,410 (73,000)
W/S	LB/SQ FT (KG/SQ M)	102 (498)	103 (503)
T/W		0.490	0.496
CRUISE MACH NUMBER		0.69	0.68

FIGURE 2-12

PR3-STOL-1846A

has been reduced approximately 16,700 (752 kg) pounds with a corresponding reduction in wing area and rated thrust. The cost study, although not yet completed, is indicating that a significant reduction in composite costs is required in order to achieve economically viable composite aircraft.

2.4 Noise Comparison of High Lift Concepts

Final design aircraft were designed to meet a noise level of 95-98 EPNdB at a 500 foot (152 m) sideline distance. Engine cycles were chosen for each lift concept that enabled the aircraft to achieve this goal with a reasonable level of noise treatment. The engine installations generally include noise treatment in the fan inlet and exhaust ducts and turbine discharge ducts. For the EBF and USB systems, low fan pressure ratio engines (1.25 and 1.30, respectively) were chosen to minimize propulsive lift noise associated with engine exhaust interaction with the flap systems. A reasonable amount of wing shielding was assumed for the USB airplane. For the AW configuration, extensive treatment in the augmentor flap system was necessary in addition to treatment in the primary exhaust and the use of a sonic inlet to contain the inlet noise.

For all acoustic studies, a NASA-approved credit for 1980 technology was used for the acoustic attenuation associated with the engine and propulsive lift sources. This technology improvement is assumed to be obtainable from on-going government and industry research programs.

Field length has a major impact on the area of noise contours as shown in Figure 2-13. The effect of increasing field length is to stretch out the 90 EPNdB noise contour along the flight path. An increase in design

EFFECT OF FIELD LENGTH ON 90 EPNdB NOISE CONTOUR

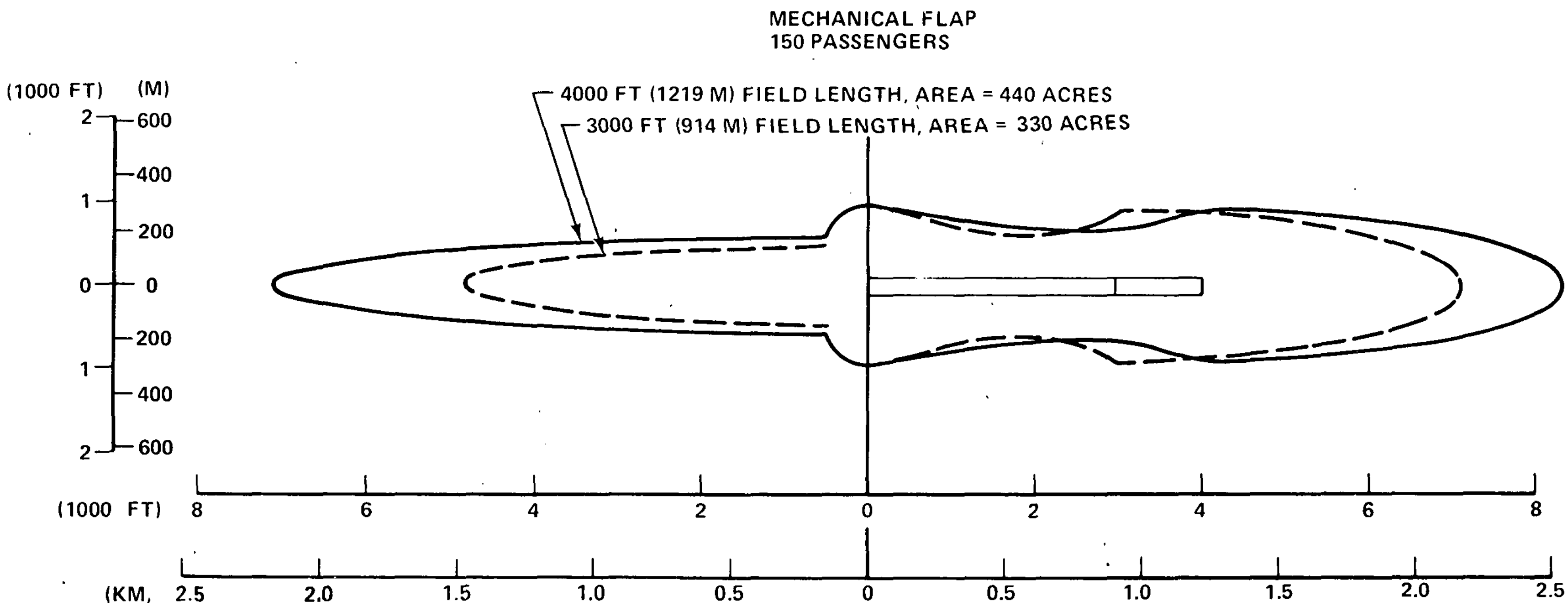


FIGURE 2-13.

PR3-STOL-1665 B

field length from 3000 to 4000 feet (914 to 1219 m) for a mechanical flap aircraft with a 500 foot (152 m) sideline noise level of 95 EPNdB will increase the area of the 90 EPNdB contour from 330 to 440 acres (132 to 176 hectares). The increase in field length produced a corresponding percentage increase in contour area. The larger area associated with the longer field length is due to the increase in takeoff ground roll (2220 feet from 1830 feet) (676 m from 558 m) and the reduction in approach and climb flight path angles (approach, 4.5 degrees from 5.4 degrees; and climb, 10.3 degrees from 10.5 degrees). These are systems analysis aircraft.

As shown in Figure 2-14, the area of the 90 EPNdB contour is larger for the EBF for takeoff but smaller for landing than that of the MF (systems analysis aircraft). The larger takeoff contour area for the externally blown flap is due to a lower climb angle (8.6 degrees vs 10.5 degrees for the mechanical flap) and the flap interaction noise and increased downward noise directivity associated with the externally blown flap configuration. The flap interaction noise does not predominate in approach, so the steeper externally blown flap flight path angle (5.6 degrees vs 5.4 degrees for the mechanical flap) results in the externally blown flap contour area being slightly smaller than that for the mechanical flap aircraft.

The effect of variations in the design sideline noise level on the 90 EPNdB noise contour is quite pronounced. The 90 EPNdB contour for the EBF 150 passenger, 3000 foot (914 m) aircraft is shown in Figure 2-15 to illustrate these variations from the community acceptance standpoint. The area of the contour multiplies threefold when the design sideline noise level is increased from 95 EPNdB to 100 - and increases almost threefold again

COMPARISON OF EXTERNALLY BLOWN FLAP AND MECHANICAL FLAP STOL

90 EPNdB NOISE CONTOURS

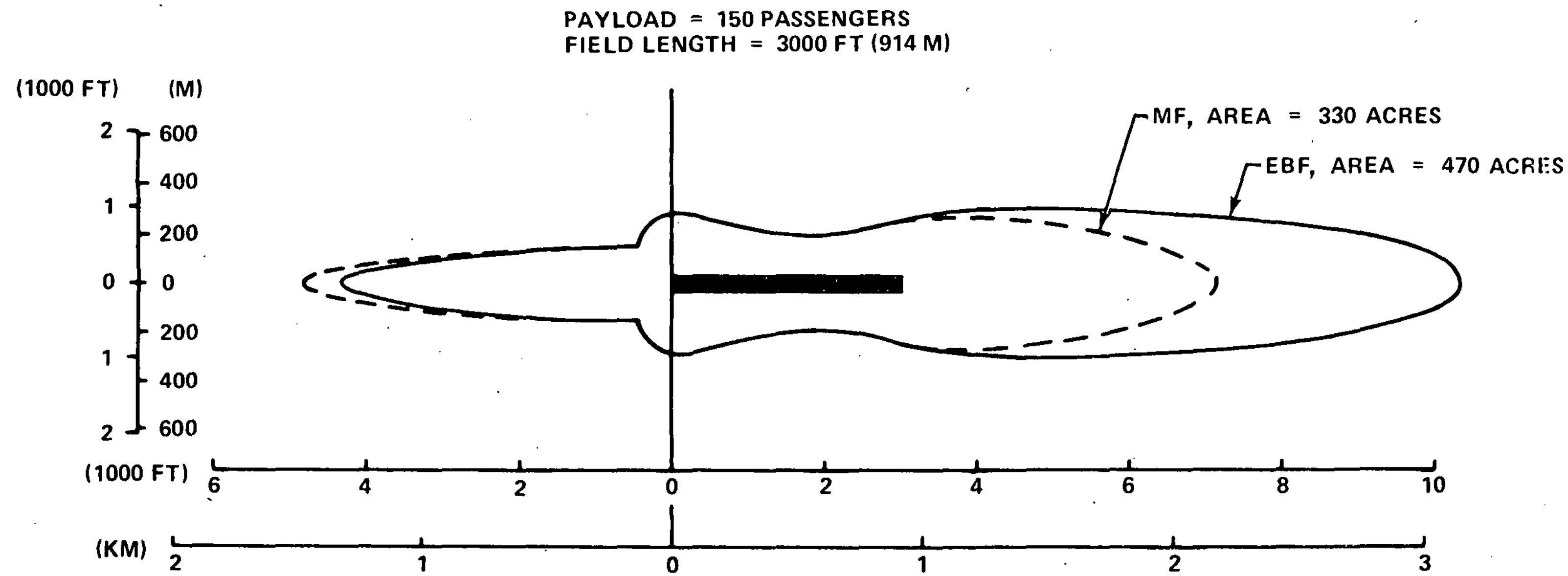


FIGURE 2-14.

PR3-STOL-1719 A

EFFECT OF DESIGN SIDELINE NOISE LEVEL ON 90 EPNdB NOISE CONTOUR

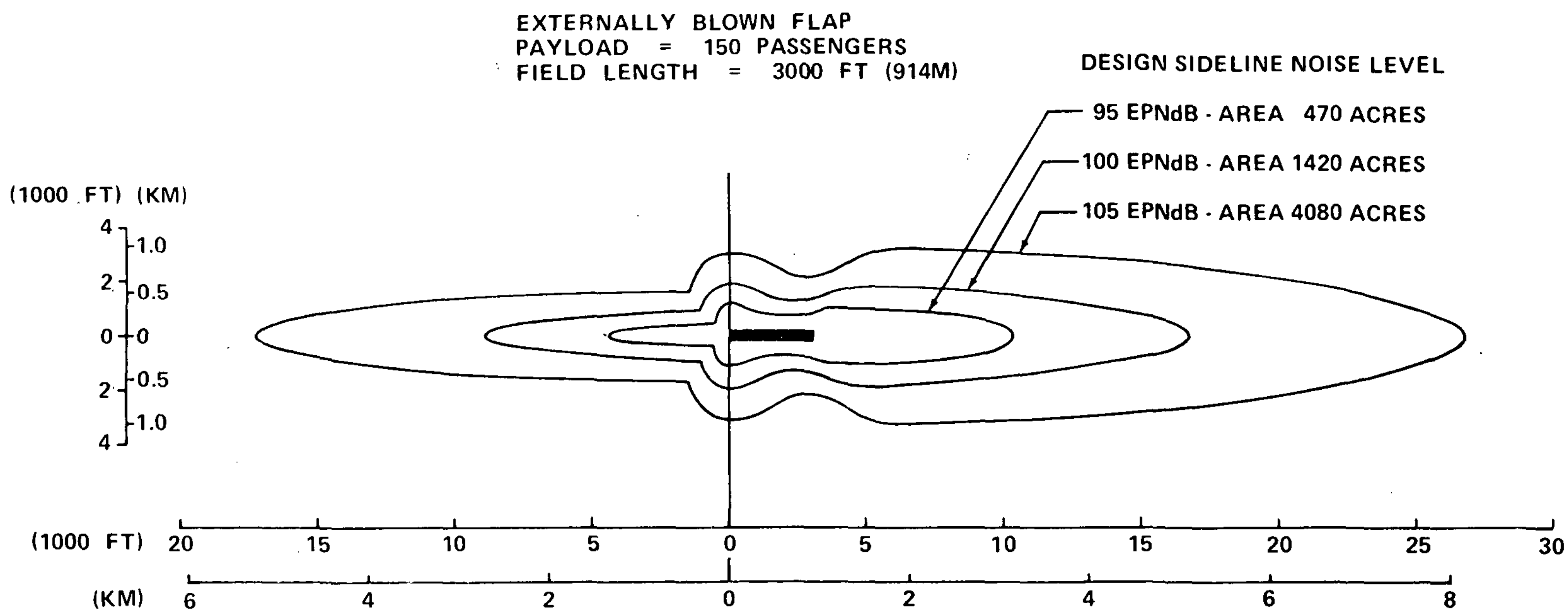


FIGURE 2-15

PR3-STOL 1666A

when the noise level is raised to 105 EPNdB.

This striking rate of increase in the area of the 90 EPNdB contours emphasizes the significance of establishing the noise criteria at the lowest feasible values commensurate with an economically viable system.

A comparison of the 90 EPNdB noise contours for the DC-10-10 and the 150 passenger, 3000 foot field length, final design externally blown flap airplane is shown in Figure 2-16. For this comparison, the design noise level for the STOL aircraft is 96 EPNdB at 500 feet sideline distance and the DC-10-10 meets the noise requirements of FAR 36. Both airplanes have fuel for a 575 statute mile stage length. The field length for the DC-10-10 for this stage length is 5500 feet. The area of the STOL aircraft noise contour is 23 percent of the DC-10 contour indicating the effect of the low design noise level used for STOL. The low noise of the DC-10 is universally recognized. This comparison is presented to establish a perspective for the previous acoustic comparisons.

COMPARISON OF 90 EPNdB NOISE CONTOURS

DC-10-10 vs EBF.150.3000

RANGE: 575 ST MI, FULL PAYLOAD, STOL 96 EPNdB AT 500 FT

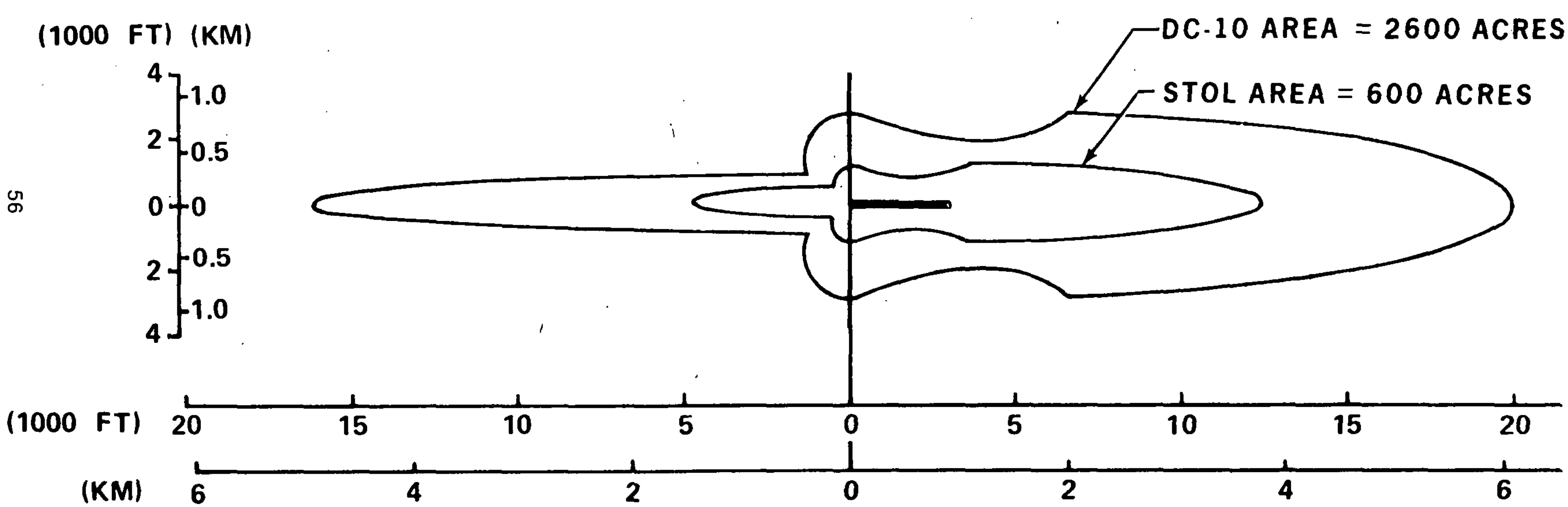


FIGURE 2-16

PR3-STOL-1896A

3.0 Operational Considerations

3.1 Scenario

The operations scenario was initiated in Phase I of the study and expanded in Phase II to cover the more detailed analyses conducted through the remainder of the study. The scenario is intended to project the general environment within which a representative STOL short-haul transportation system is postulated. Operational concepts, airline schedules, fleet composition and basing concepts are all generated within the operations scenario.

Operations Ground Rules and Assumptions

Basic ground rules are established below.

1. Each region is organized geographically into representative airline networks. Where appropriate, a region may contain more than one STOL simulated airline. Each STOL airline will be assumed to be a separate operating division of an existing corporate airline.
2. Although STOL operations will be planned at all airports considered, no commingling of CTOL and STOL air traffic will be planned. Rather, separate or dedicated STOL runways are assumed. Operations will be planned for a single STOL runway unless the analysis results in a level of operations which mignt require a second STOL runway. The number of STOLports in the same city will be minimized consistent with air passenger demand and economic factors.
3. It is anticipated that 15 to 20 major airports will be

constrained or congested by 1985 at projected growth rates of conventional air carrier traffic. These will be in addition to five which are presently airside congested and are unable to meet the potential traffic demand.

Constraints on Growth of Air Travel

A recently completed study by the President's Aviation Advisory Commission describes primary problem areas affecting the present aviation system in the United States. A principle constraint on growth of the present system exists in noise levels found at major hub airports, as well as some smaller airports located in sensitive community areas. Another constraint on growth exists in air and ground congestion. An illustration of the magnitude of the potential congestion problem is brought out by estimates of 1985 traffic at a level of 2.9 times as great as 1972. The greatest growth will be at those airports which currently are the busiest. Thus, a prime topic for study is the area of current and future constraints upon the air transportation system as a whole. Since the concept of STOL offers some physical characteristics not inherent in a conventional aircraft, it is of interest to evaluate the STOL concept for its effect upon a constrained system. Constraint is a generalized term which is used to describe any form of impediment to free flow of traffic over a given time period. For the purposes of this study, the term is subdivided into the following levels and meanings.

Level 1, Congestion - Physical

This is a specific form of constraint applied to the movement of people or vehicles. Congested airports are those at which movement is

restricted and delays or temporary stoppages occur in the movement (flow) of aircraft, airside/airport; people and baggage, terminal; or surface vehicular traffic, groundside, entering or leaving the airport across the airport boundary. This may occur either within the airport boundaries or on the network of surface streets providing community access to the airport. The Level 1 category is applied to those airports which now or in the future projection are congested to a saturation level. In this concept, no additional operations or expansion are possible.

Level 2, Constrained - Physical

This is another form of physical congestion which is less severe than Level 1. Operations occasionally are interrupted and delays occur at peak hours. However, there is sufficient area within the airport boundaries to permit the rearrangement or addition of facilities to restore free movement to aircraft, people or surface vehicles. One example is the airport at Dallas and Ft. Worth, Texas, which includes a separate STOL runway and terminal in its long-range master plan of development.

Level 3, Constrained - Social

This is a special application of the word used in a social sense wherein restrictions (physical) are placed upon the kind and level of aircraft operations permitted at the airport. Typical constraints are applied in the form of anti-noise flight profile rules, permissible exhaust emission standards, or time-of-day operations restrictions such as prohibiting jet operations between 10:00 pm and 6:00 am.

Level 4, Congested/Constrained - Social

There are some airports in the U.S. at which there are both

physical congestion arising from sheer volume of operational demands and also social constraints of Level 3 nature. Data on those congested/constrained airports included in the Baseline National Air Transportation System Overview - 1985 are included in Volume VI, Systems Analysis, Appendix A, Supporting Data for Development of STOL Systems Scenario - 1985.

STOL Operations Concept And System Requirements

The STOL operations concept in the regional expanded networks will consist of service between the following types of cities:

- o Cities with congested/constrained airports where a STOL strip is placed at an existing major air carrier airport (separate terminals).
- o Cities with congested/constrained airports where short-haul traffic is shifted to a separate airport, or
- o Uncongested/unconstrained airports where separate runways are used but CTOL and STOL travelers may commingle in the passenger terminals.

The short-haul transportation system must be designed to:

- o Satisfy air travelers with transportation from desired origins to destinations with speed, comfort, safety, reliability, adequate frequency, an acceptable fare level, and conveniénce of location of the airport.
- o Operate within environmental constraints and limitations, the most important of which is noise.
- o Be acceptable to airline and airport operators in terms of system interface compatibilities at acceptable minimum

cost of system revisions.

- o Generate sufficient revenue to be economically viable within a regulated transportation economy.
- o Provide sufficient sales opportunity for aircraft manufacturers to realize a reasonable profit on production and sales.
- o Assure continued growth of the total air travel market in meeting travel requirements by relieving actual and potential congestion at vital transportation centers.

3.2 Congestion Relief

To provide increased air traffic capacity to meet future demands, relief of congestion at major airports is foremost in future system priorities. The President's Aviation Advisory Commission has considered the following as requisite to reduction of airport congestion:

- The separation of short-haul traffic from long-haul traffic within the same airport.
- The removal of short-haul O&D traffic from large airports to suburban and military airports.

To illustrate expected problems in congestion at major airports in the Chicago Region, FAA data and analysis by the Mitre Corporation provided a reference point of departure. In Table 3-1 projected airport capacity improvement is shown. By 1975, a predicted improvement is shown of 20 percent in airport handling capacity for aircraft over the predicted annual capacity. With achievement of the six program elements shown, an expected improvement of 70 percent is estimated by 1985.

With a 70 percent improvement rate, Table 3-2 shows the possible achievement in airport operations capacity by 1985. Note that the 70 percent factor has been applied to 1970 actual operations data. Assuming that 1970 operations exceeded those for 1969 (the Mitre base), the 1985 levels would be somewhat in excess of those predicted by Mitre. On the same Table, unconstrained growth is shown forecasted at 1985 levels.

TABLE 3-1

FAA'S INCREASED AIRCRAFT HANDLING CAPACITY AIRPORT PROGRAM

PROGRAM ELEMENT	PERCENT CAPACITY INCREASE BY 1975	PERCENT CAPACITY INCREASE BY 1985
1. CONSTRUCTION AND EFFECTIVE USE OF HIGH-SPEED EXITS AND ENTRANCES	0	5
2. SEPARATION OF AIRCRAFT BY PERFORMANCE	10	10
3. TWO MILE LONGITUDINAL SEPARATION	0	30
4. COMPUTER AIDED SPACING	10	10
5. GROUND GUIDANCE AND CONTROL	0	5
6. HIGHER LEVELS OF AUTOMATION	0	10
TOTAL INCREASE OVER 1969 AIRCRAFT HANDLING CAPACITY	20%	70%

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TABLE 3-2

RUNWAY CAPACITY vs AIRCRAFT OPERATIONS

CHICAGO REGION

AIRPORT	AIRCRAFT OPERATIONS FORECAST 1985 (ANNUAL 000)	AIRCRAFT OPERATIONS CAPACITY 1985 (ASSUME 70 PERCENT IMPROVEMENT OVER 1970) (ANNUAL 000)
PITTSBURGH	368	257
CLEVELAND	348	222
DETROIT	444	346
CHICAGO	1,206	1,020
MILWAUKEE	236	126
MINNEAPOLIS/ST. PAUL	270	216
ST. LOUIS	330	317
DENVER	317	296
BUFFALO	206	122
ROCHESTER	178	92
CINCINNATI	245	158

PR2-STOL-1165A

Congestion relief is acnieved at O'Hare International Airport by shifting STOL short-haul O&D traffic in the Chicago Region to Meigs Field and Midway Airport. With a total number of movements of 1,206,000 projected in 1985, the STOL analysis showed a shift of about 141,000 aircraft movements from O'Hare to the two short-haul airports. This represents a relief of about 12 percent to projected 1985 levels at O'Hare.

Congestion relief is provided in the Chicago Region as a result of application of study ground rules and inclusion of O&D city-pairs with demand of 50,000 travelers and above per year. Analyses were made of similar airport operations at St. Louis and Detroit plus Philadelphia in the Northeast Region and Atlanta in the Southeast Region. Congestion relief at the major air carrier airports in each of these regions is shown in Figure 3-1.

1985

AIRPORT CONGESTION RELIEF

SELECTED HUBS - ANNUAL OPERATIONS

AIRPORT	TOTAL AIRCRAFT MOVEMENTS (000)	STOL O&D SHORT HAUL PASSENGERS (000)	STOL AIRCRAFT MOVEMENTS (000)	AIRCRAFT MOVEMENTS REDUCED (PERCENT OF TOTAL)
CHICAGO O'HARE	1,206	12,700	141	11.7
ATLANTA INTERNATIONAL	725	9,605	107	14.8
DETROIT METROPOLITAN	444	6,552	73	16.3
PHILADELPHIA INTERNATIONAL	409	5,605	62	15.2
ST. LOUIS LAMBERT	330	4,827	54	16.4

FIGURE 3-1

PR3-STOL-1792

4.0 AIRPORT SITE SELECTION

4.1 Site Location

Over 200 airports were initially investigated within the Chicago, Northeast, California, Southern, Southeastern, and Northwest Regions to form a national STOL network. The final selected network consists of a total of 94 airports, Figure 4-1, including 72 existing air carrier airports, 20 general aviation airports, and 2 new urban STOLports. The selected airports are considered representative for STOL operations. System implementation and operation is not necessarily dependent on the specific airports selected.

Airport design and operational criteria were established using the baseline E.150.3000 airplane. Three basic STOL airport options as presented in Figure 4-2 were analyzed. Most existing air carrier airports were found to be generally compatible with STOL operations. General aviation airports are considered compatible to a lesser degree and will require a greater degree of modification. New urban STOLports require extensive work but have the advantage of optimization for STOL short-haul operations.

Airport Costs

Airport and air traffic control implementation costs were developed for each of the 94 network airports for an upgraded third generation ATC system (Figure 4-3). The objective of the airport costing study was to determine the expenditures required to correct the deficiencies identified during the airport airside compatibility evaluation using the baseline E.150.3000 STOL aircraft. Airport landside requirements were based on STOL passenger demand and scheduled flight frequencies obtained from the systems analysis studies.

NATIONAL SHORT-HAUL BASELINE AIRPORTS

94 AIRPORTS

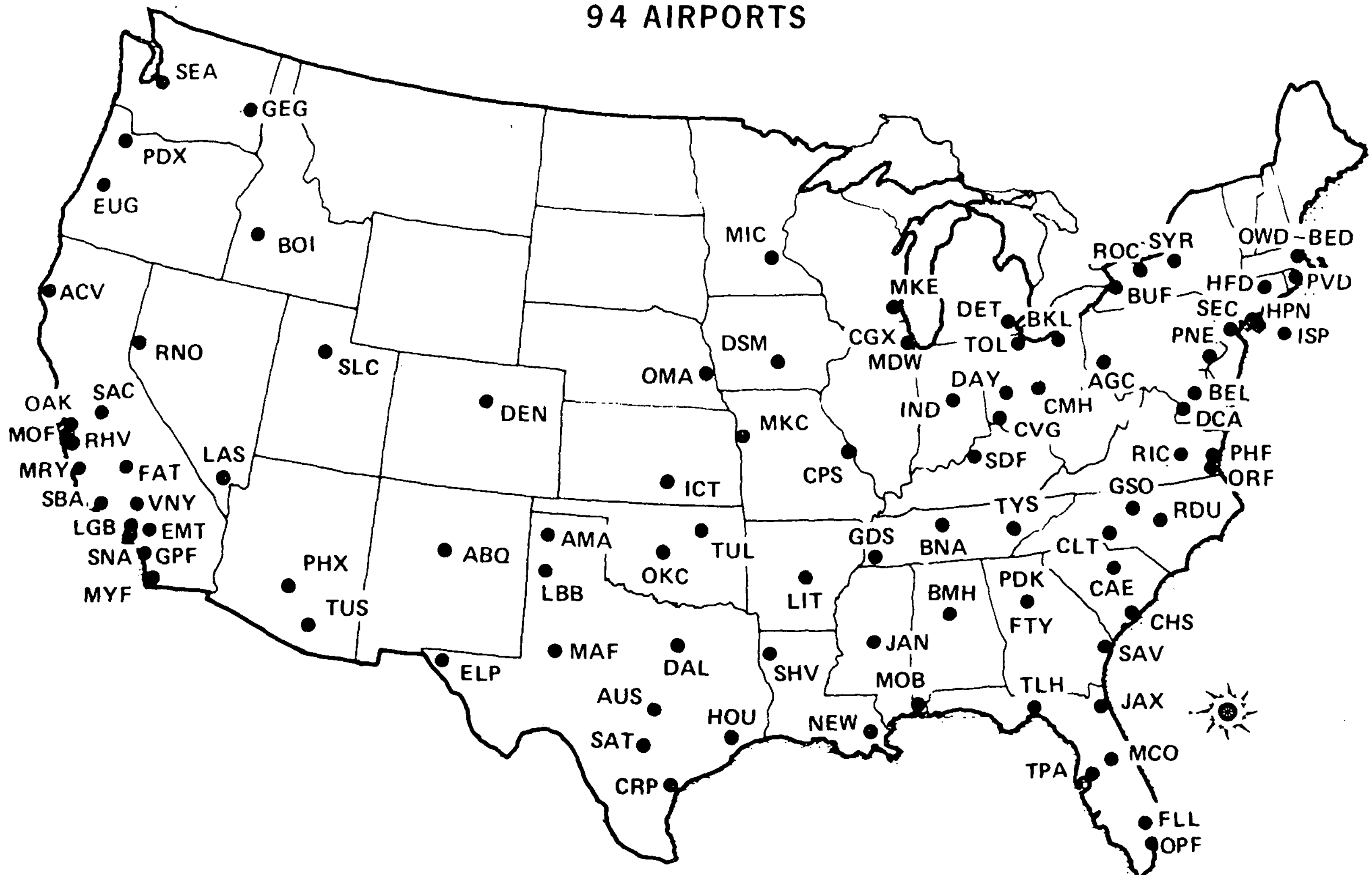


FIGURE 4-1

STOL AIRPORT OPTIONS

AIRPORT TYPE	ADVANTAGE	DISADVANTAGE
AIR CARRIER	o INTERCONNECTING PASSENGERS o ENVIRONMENTAL APPROVAL EASIER o COMPATIBLE ATC FACILITIES o SHORTEST TIME TO IMPLEMENT o MANY FACILITIES EXIST	o INCREASED GROUND CONGESTION o NOT OPTIMIZED FOR STOL o LOWER PRIORITY OF FACILITIES o MODERATE ATC EXPENSE
GENERAL AVIATION	o AVIATION PRECEDENT o GOOD GROUND ACCESS o BASIC FACILITIES EXIST o FEW ATC FACILITIES	o QUESTIONABLE ENVIRONMENTAL APPROVAL o NEED MANY NEW FACILITIES o LONGER TIME TO IMPLEMENT o NOT OPTIMIZED FOR STOL o EXTENSIVE ATC EXPENSE
NEW SITE (GROUND LEVEL)	o CONVENIENT TO POPULATION CENTER o GOOD GROUND ACCESS o OPTIMIZED FOR STOL	o DOUBTFUL ENVIRONMENTAL APPROVAL o LONGEST TIME TO IMPLEMENT o HIGH COST-LAND SCARCITY o MAXIMUM ATC EXPENSE

FIGURE 4-2.

AIRPORT COSTS

(× $1000)

	CHICAGO REGION	NORTHEAST REGION	CALIFORNIA REGION	SOUTHERN REGION	SOUTHEAST REGION	NORTHWEST REGION	TOTAL
RUNWAYS	$1,215	$ 2,002	$ 1,014	$ 442	$ 1,332	$ 0	$ 6,005
TAXIWAYS	327	927	340	268	333	0	2,195
GATES/APRONS	13,735	18,090	23,785	11,390	21,775	2,680	91,455
TERMINAL BUILDINGS	24,450	28,830	37,425	16,965	30,240	3,600	141,510
PARKING	1,281	2,670	2,855	1,340	2,313	181	10,640
ATC	20,868	10,255	21,028	18,326	25,333	5,128	100,938
TOTAL	$61,876	$62,774	$86,447	$48,731	$81,362	$11,589	$352,743

FIGURE 4-3

PR3-STOL-1740

Fifty percent of the cost of runways, taxiways, and gates/aprons would be funded by the airport and airway development program in accordance with procedures administered by the FAA. The balance would be paid by the community. The cost of terminal buildings and parking areas would be borne primarily by the airlines. The ATC costs would be supported by the FAA. The ATC costs include a microwave ILS system and represent a "maximum" ATC cost for a STOL network. If the ATC costs are paid for by CTOL and runways are co-shared with CTOL, a "minimum" cost is obtained. This will require a VASI (Visual Approach Slope Indicator) and a V/STOL approach lighting system for STOL aircraft. The total ATC cost would be reduced approximately 85 percent.

There are no land costs included for the two new STOLports and the cost for airport access and egress was not determined. The cost of maintenance facilities is included in Volume VI - Systems Analysis.

4.2 User and Non-User Benefits

User Benefits

The primary benefits to the short-haul air passenger accrue from the fact that general aviation and new site airports in most instances will be located closer to his point of departure and/or arrival than those of the CTOL system. This provides greater convenience, shorter surface travel time and a decrease in surface travel cost.

A secondary user benefit results from removal of short-haul air traffic from congested major airports thereby reducing both surface and air traffic delays associated with these airports. The reduction of delay time

can be translated directly into dollar cost savings to the air passenger. Interconnecting passengers also benefit from the reduction in air traffic congestion and delay.

SUMMARY OF USER BENEFITS

- Reduced total travel time for short-haul passengers
- Reduction in delays due to airport surface traffic congestion
- Potential reduction in total trip cost for short-haul and interconnecting passengers
- Increased travel convenience for short-haul passengers

Non-User Benefits

Establishment of consistent criteria or standards for determining whether an item is a national, regional, or local benefit was found to be essential, since in many instances the classification is one of degree. Therefore, the following criteria were established to simplify classification:

National Benefit - Those items which contribute to the achievement of established national goals, or which result in a measurable change in national statistics as published in the "U.S. Statistical Abstract."

Regional Benefit - Those items which contribute to the established goals or general welfare of a state, a recognized geographical area, or a politically defined region. A Standard Metropolitan Statistical Area (SMSA) was arbitrarily established as the smallest individual area included in the regional classification.

Local Benefit - Those items which contribute to the established goals or general welfare of an individual city, borough, county, or community smaller than a SMSA (or various combinations of the above). For example, some airports impact on as many as ten or more local communities, some legally or politically defined -- others not.

The reduction in congestion at major hub airports benefits all three categories, but is primarily considered a national benefit. Reduction in noise impact will provide most relief at the local level. Potential employment and economic opportunity are primarily regional in scope.

Almost all non-user benefits are directly or indirectly related to the short field capability of STOL aircraft.

SUMMARY OF NON-USER BENEFITS

	NATIONAL	REGIONAL	LOCAL
o Reduced congestion at major hub airports	X	X	X
o Extended life of major CTOL airports	X	X	X
o Reduced airline delay cost	X	X	
o Significant reduction in noise impact		X	X
o Lowest environmental impact of any comparable short-haul transportation system-air or surface	X	X	X
o Potential employment and economic opportunities		X	X

4.3 Community Acceptance

The various factors associated with community acceptance (e.g., noise, emissions, congestion, land use) were analyzed in-depth and the extent of the environmental impact of STOL operations was determined at twelve selected airports (Figure 4-4). These airports were carefully selected with respect to location, type, land use, and community characteristics and are considered representative of other network airports of similar type. Special emphasis was placed on the sociological aspects of community acceptance. The need for extensive research in this field is emphasized. A field investigating team made physical inspections of the majority of these sites for first-hand evaluation.

One of the typical airports investigated was Laurence G. Hanscom Field which is a joint-use military airport located near Bedford, Massachusetts at the western boundary of the Boston metropolitan area. It is typical of many of the airports examined for STOL short-haul operations. It is a relief airport to Boston-Logan and both are operated by the Massachusetts Port Authority. The airport has good ground access but it becomes congested in the airport vicinity because of vehicular traffic from the large electronic manufacturing plants and the city of Bedford.

The local air quality near Bedford is relatively uncontaminated, the area being semi-rural. A new STOL short-haul operation will add very little to this contamination.

Existing runway 5/23 at Hanscom was selected as a STOL runway due to its proximity to the existing terminal area. As shown in Figure 4-5, the 95 EPNdB footprint of the baseline E.150.3000 aircraft is essentially

AIRPORTS SELECTED FOR COMMUNITY EVALUATION

ADJACENT LAND USE / AIRPORT TYPE	RESIDENTIAL	RES/INDUSTRIAL	INDUSTRIAL
PRIMARY CTOL (>1,000,000 PSGR/YR)	WASHINGTON NATIONAL	BOSTON LOGAN	-
SECONDARY CTOL (50,000 TO 1,000,000)	CHICAGO MIDWAY	ORANGE COUNTY (SANTA ANA)	NORTH OAKLAND
GENERAL AVIATION	EL MONTE (LOS ANGELES)	MONTGOMERY FIELD (SAN DIEGO)	MEIGS FIELD (CHICAGO)
MILITARY/JOINT USE	-	HANSCOM FIELD (BEDFORD)	NAS MOFFETT FIELD (MOUNTAIN VIEW)
NEW CBD SITE	-	-	GENERAL PATTON (LOS ANGELES)
NEW SUBURBAN SITE	-	SECAUCUS (NEW JERSEY)	-

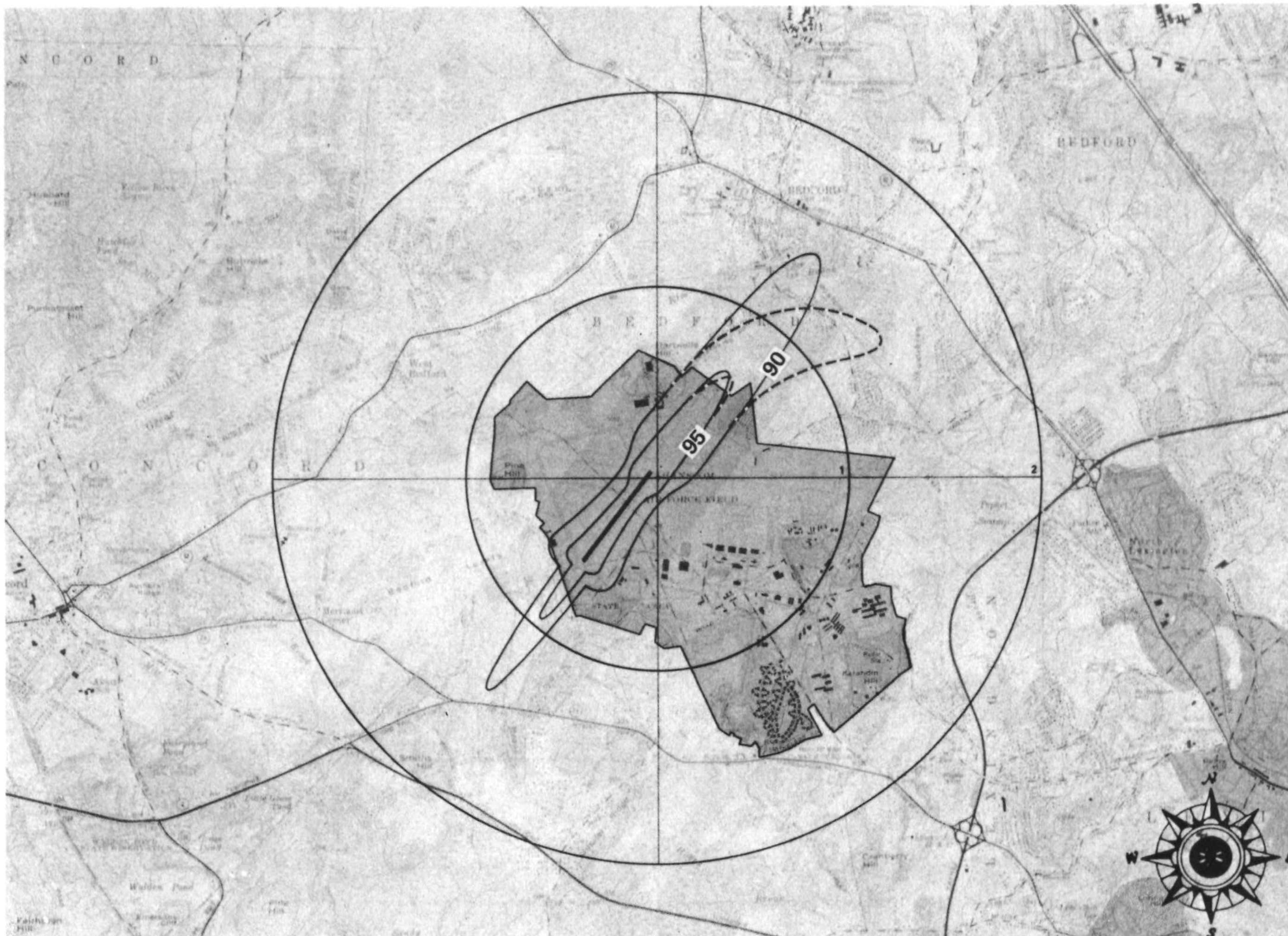
PR2-STOL-1223 C

FIGURE 4-4

COMMUNITY IMPACT - HANSCOM FIELD

E · 150 · 3000 95 AND 90 EPNdB

2 ST MI (3.2 km) RADIUS IMPACT ZONE



PR3-STOL-1491

FIGURE 4-5

contained within the airfield boundary. Approximately 54 percent of the 90 EPNdB footprint also is airport contained. The departure lobe extends into the outskirts of Bedford. The use of a curvilinear departure path as shown, significantly minimizes the impact on the Bedford area. Use of runway 11/29 results in 85 percent airport containment of the 90 EPNdB footprint, with practically no impact on the urbanized area and may be preferable from community noise considerations.

Summarizing the above evaluation, STOL operations at Hanscom Field will:

- o Result in some increase in surface traffic congestion, however, this can be alleviated by local roadway improvements.
- o Result in a slight, but almost immeasurable increase in air pollution in the localized area due to increased automobile traffic. STOL, with lower emission levels than CTOL, will provide an overall reduction in total aircraft emissions within the Boston Metropolitan area (assuming an equivalent number of STOL versus CTOL movements).
- o Result in relatively low aircraft noise levels (in the NEF 25-27 range) with minimum impact on the adjoining community.

Community acceptance problems are anticipated, however, due to existing community concern over commercial expansion of the airport.

Airspace, airport, and ground access congestion were investigated to determine operational constraints and methods of relief. Ground access congestion was found to be a major constraint at almost all high

density airports. Solution to the problem rests with governmental agencies other than airport owners or sponsors. The primary STOL airport implementation problems were found to be:

- The delay involved in preparing and processing Environmental Impact Statements (EIS).
- Airport development is usually low on the list of community funding priorities. Additional Federal funding assistance, or economic incentives, may be required to implement the STOL airport network.
- Almost universal community objection to any type of airport expansion or construction. Programs for achieving community acceptance and guidelines for public education programs should be pursued.

5.0 ECONOMIC ANALYSIS

5.1 Airplane Cost Analysis

5.1.1 General. - Cost was treated and emphasized as a decisive system parameter in the system development process of design, selection and evaluation of airplane configurations and short-haul air transportation systems. Cost analysis was integrated throughout this process and supported trade studies, sensitivity analyses and cost estimating. The concept of total system cost involved a systematic and organized identification of the resources and interfaces required throughout the economic life of the system.

THe same basic procedures were used in Phase I and Phase II to develop and apply costs. These procedures involved the use of a consistent set of computations to determine the relative cost differences among the high-lift designs. In addition, the computations were derived from historical information to assure consistency of the calculated costs with the cost levels that would be obtained if the airplanes were actually manufactured. All analyses are based on 1972 dollars unless otherwise specified.

5.1.2 Phase I Airplanes. - The parametric Phase I airplanes varied in payload from 50 to 200 passengers and field length from 1500 to 3000 feet (457 to 914 m). Based on aircraft performance screening and systems analysis procedures, six propulsive-lift and two high-lift mechanical flap designs were selected for detailed analysis in Phase II as discussed earlier. Detailed economic analyses for the Phase I aircraft are contained in Volume V - Economics.

5.1.3 Phase II Airplane Characteristics and Prices. - The characteristics and prices of Phase II airplanes, for both systems analysis aircraft and final design aircraft, are shown in Table 5-1. In Phase II the economic analyses focused on the systems analysis aircraft. The dominant effects of airplane design, advanced propulsion technology and noise level criteria on the airplane are examined in terms of subsystem price. Prices displayed are cumulative averages for a production of 400 airframes and 2000 engines/nacelles. An airplane manufacturer's profit of 10 percent is included in the prices for all four subsystems. The prices contain the appropriate allocation of R&D expenditures.

Technical characteristics which are used to develop prices are manufacturer's weight empty (MWE), cost weight (CW) and uninstalled thrust per engine. The relationship between airframe price and cost weight is consistent for all aircraft except the augmentor wing - i.e. a weight increase produces a proportional price increase. The augmentor wing airframe price includes an additional price increment to account for the complexities of the airflow ducting system. This is the reason that the airframe price for the augmentor wing exceeds the E150.2000 even though its cost weight is below that of the E150.2000 airplane.

Of the propulsive lift concepts and at equal thrust levels, the EBF airplanes exhibit the highest engine prices. The EBF airplanes are configured with variable pitch fan engines which are more expensive than the fixed pitch fan on the USB airplane. The AW airplane is configured with low bypass ratio engines which are not as expensive as the EBF engines.

TABLE 5-1.

PHASE II AIRPLANE CHARACTERISTICS AND PRICES

AIRPLANE TYPE / FIELD LENGTH FT	E 150 2000	A 150 2000	U 150 2000	E 100 3000	E 150 3000	M 150 3000	E 200 3000	M 150 4000
SYSTEM ANALYSIS AIRPLANES [A]								
MWE, LB	148,900	144,360	173,540	75,860	110,900	125,340	151,880	103,070
CW, LB	131,236	126,504	156,300	65,562	96,540	112,150	132,906	90,030
THRUST PER ENGINE, LB	26,830	22,200	27,475	14,520	21,270	34,840	28,790	34,390
ACQUISITION PRICE, $M								
AIRFRAME	9.017	9.268	9.996	5.000	6.931	7.708	9.090	6.317
NACELLES	0.428	0.536	0.964	0.252	0.352	0.556	0.452	0.546
ENGINES	3.764	3.036	3.300	2.972	3.412	2.266	3.872	2.244
AVIONICS	0.628	0.628	0.628	0.628	0.628	0.628	0.628	0.628
TOTAL	13.837	13.468	14.888	8.852	11.323	11.158	14.042	9.735
FINAL DESIGN AIRPLANES								
MWE, LB	141,710	146,530	169,380	70,170	99,770	136,290	127.880	104,270
CW, LB	124,610	131,910	150,980	60,560	87,110	122,430	112,330	92,800
THRUST PER ENGINE, LB	25,830	19,200	29,490	13,200	18,260	36,990	22,925	32,450
ACQUISITION PRICE, $M								
AIRFRAME	8.625	9.595	9.652	4.683	6.370	8.343	7.906	6.516
NACELLES	0.412	0.488	0.992	0.228	0.308	0.578	0.376	0.524
ENGINES	3.720	2.884	3.412	2.884	3.212	2.332	3.520	2.200
AVIONICS	0.628	0.628	0.628	0.628	0.628	0.628	0.628	0.628
TOTAL	13.385	13.595	14.684	8.423	10.518	11.881	12.430	9.868

(A) *USED FOR PHASE II ECONOMIC ANALYSIS.*

PR3-STOL-1848

Nacelle prices are higher for the AW than the EBF because it is designed with a translating center body sonic unit which is much heavier and more complex than the nacelles on the EBF concept.

Each airplane, regardless of lift system, incorporates the same avionics system as indicated by the constant price of $628,000 per system. For the MF airplanes to achieve the same level of ride quality as the propulsive lift concepts, the total complement of avionics would be comparable.

5.1.4 Direct Operating Cost. - The direct operating cost for the Phase II systems analysis aircraft, subdivided by cost element, is shown in Table 5-2 for a stage length of 575 statute miles (926 km). The DOC's for the airplanes having shorter field lengths (2000 feet (610 m) and lower payloads (100 passengers) are substantially higher than the other airplanes. This is also illustrated in Figure 5-1.

In comparison with the 3000 foot (915 m) field length airplanes, a 2000 foot (610 m) design increases cost per airplane mile by about 60 cents or about 20 percent, while a 4000 foot (1220 m) field length reduces cost per airplane mile by about 45 cents or about 14 percent, Figure 5-2. As shown in Figure 5-3, a 100 passenger airplane has a 20 percent higher cost per available seat-mile than the 150 passenger baseline, while a 200 passenger airplane has about a 17 percent lower cost per available seat-mile.

The direct operating cost for most of the final design aircraft shown earlier in Table 2-1 are lower than the systems analysis aircraft shown in Table 5-2. This is due to the lower gross weight and other favorable effects stemming from the slight relaxation in sideline noise levels based on the acoustic trade studies (95 EPNdB for the systems analysis aircraft

TABLE 5-2
PHASE II DIRECT OPERATING COSTS BY RESOURCE ELEMENT
575 St. Mi. (925 km) 2500 HRS. UTILIZATION
DOLLARS PER CYCLE

LIFT CONCEPT	EBF				MF		AW	USB
PASSENGER CAPACITY	150	100	150	200	150	150	150	150
FIELD LENGTH - FT.	2000	3000	3000	3000	3000	4000	2000	2000
(m)	(610)	(915)	(915)	(915)	(915)	(1220)	(610)	(610)
FLYING OPERATIONS								
CREW	294.98	287.36	288.62	290.39	288.12	277.70	277.15	297.68
FUEL	315.00	171.00	246.60	325.80	271.80	241.20	457.20	334.80
OIL	0.72	0.73	0.72	0.71	0.36	0.35	0.68	0.72
INSURANCE	160.51	103.39	130.44	159.52	127.65	108.25	146.53	172.70
SUBTOTAL	771.21	562.48	666.38	776.42	687.93	627.50	881.56	805.90
DEPRECIATION								
AIRPLANE	668.79	430.80	543.50	664.65	531.86	451.05	610.55	719.59
SPARES	94.17	64.78	78.91	93.96	69.39	60.70	81.70	95.88
SUBTOTAL	762.96	495.58	622.41	758.61	601.25	511.75	692.25	815.47
MAINTENANCE								
AIRFRAME LABOR	82.58	48.92	65.05	82.65	72.70	60.68	77.91	94.59
ENGINE LABOR	52.47	37.82	45.56	54.09	30.78	29.96	44.95	53.25
SUBTOTAL	135.05	86.74	110.61	136.74	103.48	90.64	122.86	147.84
AIRFRAME MATERIAL	78.94	46.22	61.82	79.00	69.28	57.67	79.59	90.82
ENGINE MATERIAL	152.91	121.29	137.97	155.12	91.21	88.64	118.21	134.06
SUBTOTAL	231.85	167.51	199.79	234.12	160.49	146.31	197.80	224.88
BURDEN	243.09	156.13	199.10	246.12	186.26	163.16	221.16	266.11
SUBTOTAL	609.99	410.38	509.50	616.98	450.23	400.11	541.82	638.83
TOTAL COST DOLLARS/CYCLE	2144.16	1468.44	1798.29	2152.01	1739.41	1539.36	2115.63	2260.20
DOLLARS PER BLOCK HOUR	1479	1006	1249	1515	1216	1107	1556	1559
DOLLARS PER APL. MILE	3.72	2.55	3.12	3.74	3.02	2.67	3.67	3.92
¢/ASSM	2.48	2.55	2.08	1.87	2.01	1.78	2.45	2.62
¢/ASKM	1.54	1.59	1.30	1.17	1.25	1.10	1.53	1.63

DIRECT OPERATING COST vs STAGE LENGTH

SYSTEMS ANALYSIS AIRCRAFT

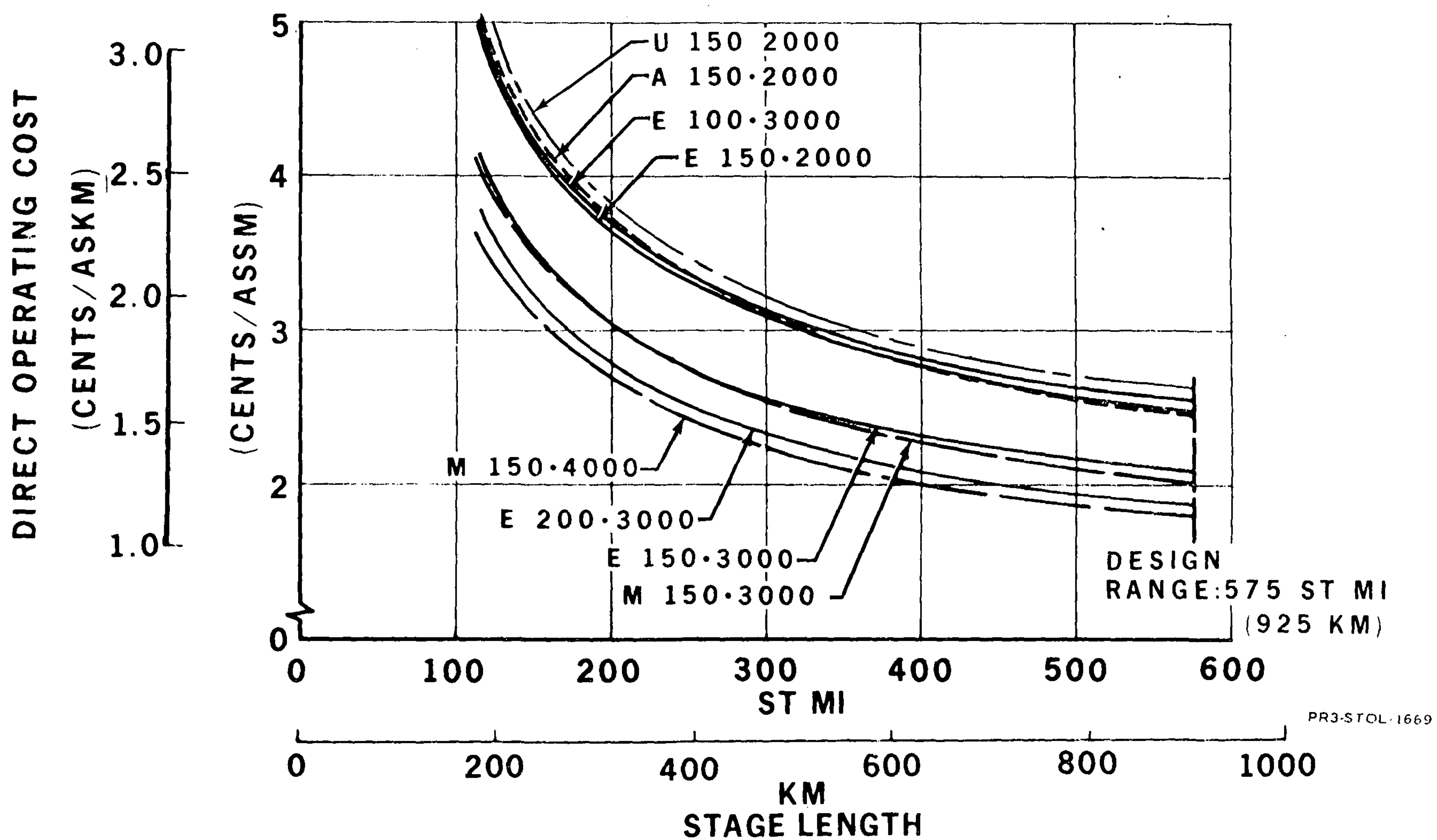


FIGURE 5-1

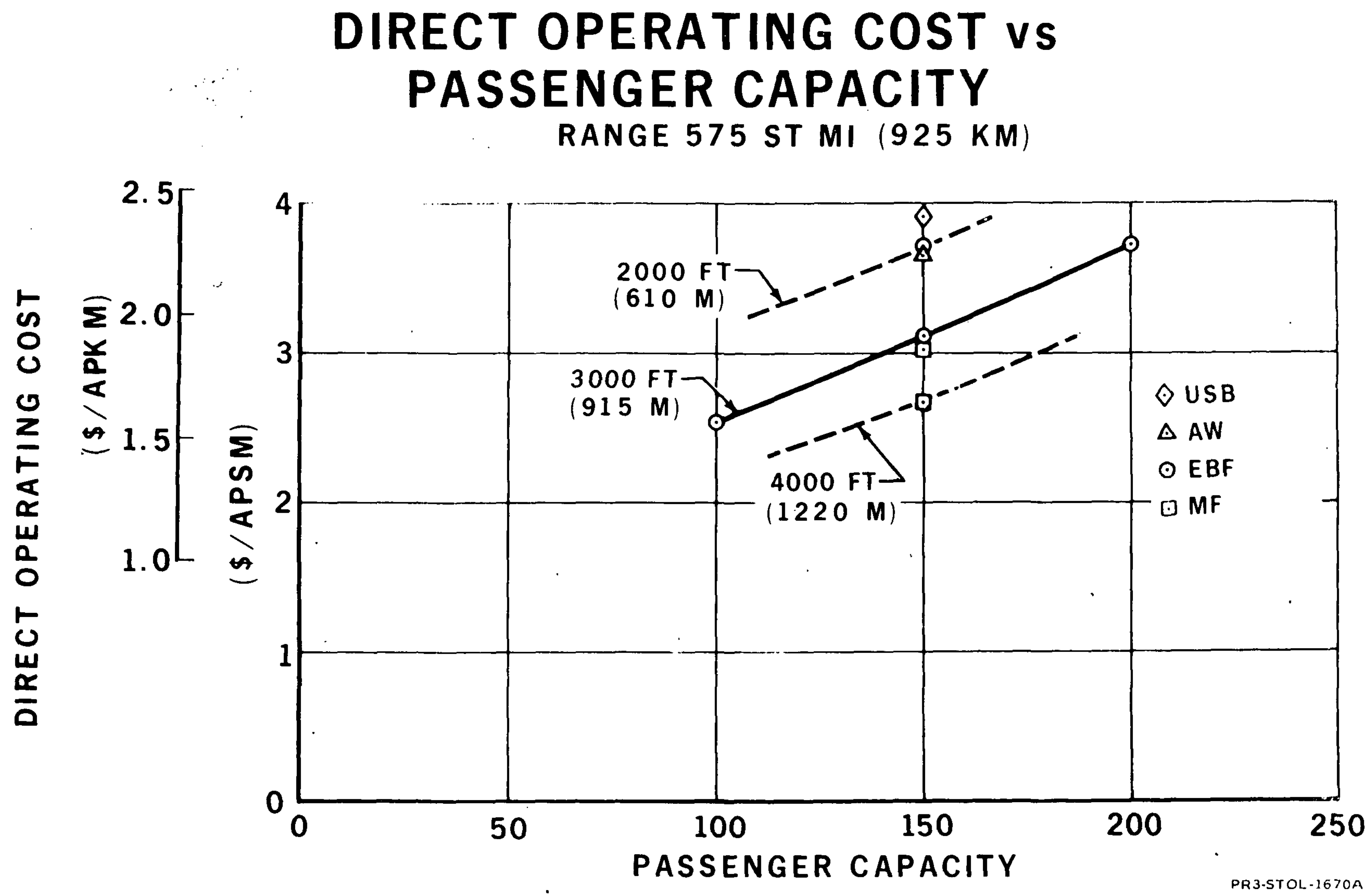

DIRECT OPERATING COST vs
PASSENGER CAPACITY
RANGE 575 ST MI (925 KM)
DIRECT OPERATING COST
($/APK M)
2.5
2.0
1.5
1.0
($/APSM)
4
3
2
1
0
0
50
100
150
200
250
PASSENGER CAPACITY
2000 FT
(610 M)
3000 FT
(915 M)
4000 FT
(1220 M)
USB
AW
EBF
MF
PR3-STOL-1670A

FIGURE 5-2.

DIRECT OPERATING COSTS vs PASSENGER CAPACITY

RANGE 575 ST MI (925 KM)

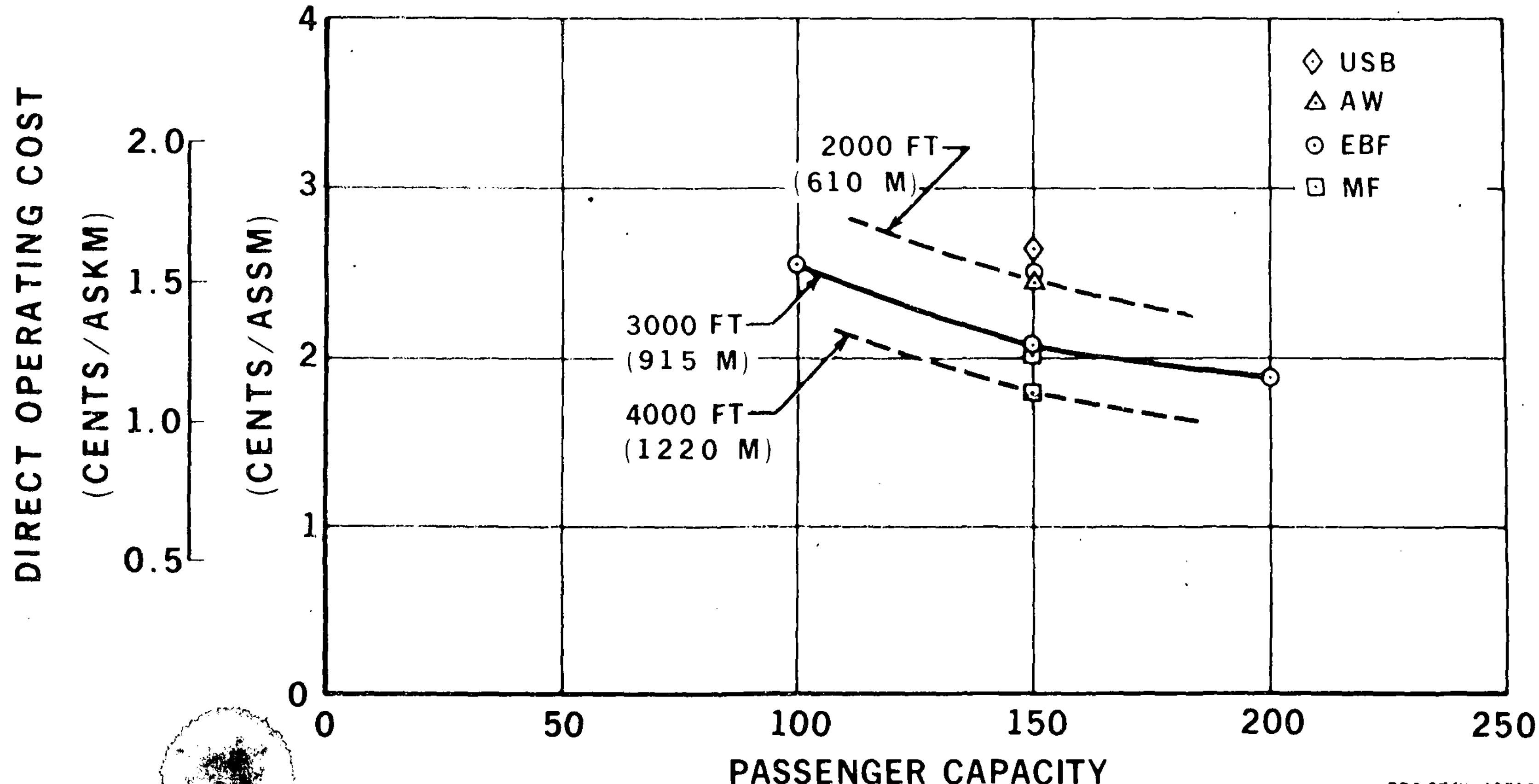


FIGURE 5-3.

in comparison with 95-98 EPNdB for the final design aircraft).

5.1.5 Direct Operating Cost Sensitivity. - The sensitivity to the primary design, procedural, and pricing variations is shown in Figure 5-4. As STOL systems mature and successful operating experience accumulates the hull insurance rate should approach the nominal one percent level representative of many operations. This change would reduce baseline direct operating cost per block hour by about $44 or 3.5 percent as shown in Figure 5-4. The largest impact would probably be noticed in the depreciation as a result of different utilization rates. The nominal figure is based upon 2500 hours per year or about 6 2/3 hours per day. For an annual utilization of 2750 hours, the DOCs could drop by $50 per block hour or 4 percent. Initial price variations on the order of $1 million produce a 4 percent change in DOC as does a total maintenance variation of 10 percent. The sensitivity to SFC is less; a 16 percent variation in specific fuel consumption (SFC) results in a 2 percent change in direct operating cost.

5.1.6 Indirect Operating Cost Model. - The indirect operating cost model used in this study predicts the cost for ten indirect activities by relating historical airline indirect costs to aircraft operational parameters such as revenue passenger miles, maintenance and gross weight. The activities used in predicting the costs, and the related factors, are reported in Volume V, Economics.

5.1.7 Modifications to IOC Cost Model. - Factors based on the cost data from the domestic trunk carriers were not completely applicable to this study because of the unique operational characteristics and assumptions made for the STOL system. Therefore, during Phase I several modifications were

DIRECT OPERATING COST SENSITIVITIES

Δ $/BLOCK HR • E150.3000.68 • STAGE LENGTH 575 ST MI (926 KM)

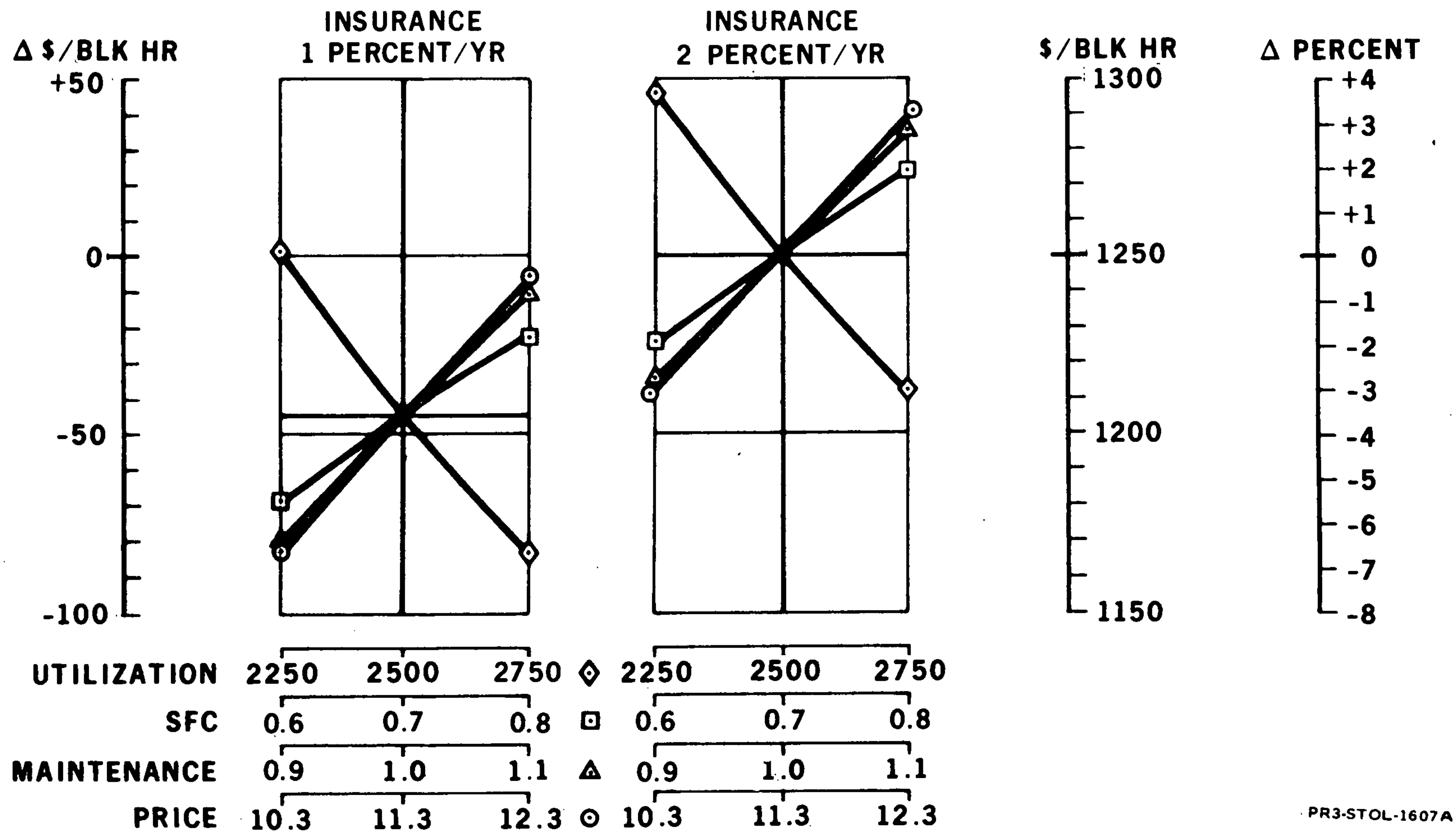


FIGURE 5-4.

reduced by about 25 percent because it is anticipated the STOL system would use only one airplane type. When the number of airplane models is reduced the cost of maintaining ground property and equipment would be reduced. Airplane control cost was reduced by 20 percent because the regional STOL systems could use a centralized organization for the flight planning, crew scheduling and meteorology functions. Passenger ground service costs were reduced by 35 percent. The lower constants were based on the experience of a representative short-haul carrier which represents an austere short-haul service level rather than the more extensive service provided trunk passengers.

During Phase II an extensive review of the Phase I indirect formulation was undertaken. Inspection of the operating results of short-haul carriers did not provide conclusive evidence to substantiate further reductions of IOC estimates. Therefore, the Phase I method was used without further changes throughout Phase II. The IOCs for the Phase II airplanes are displayed in Table 5-3.

On balance, the IOC estimates appear to be conservative projections of regional STOL expense after the regional systems have matured. During the early years the estimates may be a little optimistic because lower traffic levels would not fully absorb certain expenses; viz, the cost of promotional and general management activities.

TABLE 5-3

PHASE II INDIRECT OPERATING COST SUMMARY

575 ST. MILES (925 KM)   2500 HOUR UTILIZATION

CONFIGURATION	DOLLARS PER AIRPLANE MILE	(KM)	CENTS PER AVAILABLE SEAT MILE	(KM)
Externally Blown Flap				
E150.2000	2.15	(1.34)	1.43	(0.89)
E100.3000	1.38	(0.86)	1.38	(0.86)
E150.3000	2.00	(1.25)	1.33	(0.83)
E200.3000	2.64	(1.65)	1.32	(0.82)
Mechanical Flap				
M150.3000	2.03	(1.27)	1.35	(0.84)
M150.4000	1.94	(1.21)	1.29	(0.81)
Augmentor Wing				
A150.2000	2.15	(1.34)	1.43	(0.89)
Upper Surface Blowing				
U150.2000	2.24	(1.40)	1.49	(0.93)

5.2 Airline Economics

5.2.1 Return on Investment

5.2.1.1 Phase II - In Phase II, the CAB fare structure (Phase 7) was used and the ROIs calculated for the study aircraft in the six main regional networks. The data for an average stage length in a representative region (Chicago) is shown in Figure 5-5. Although the viability threshold goal is unique to each company, it generally falls in the range shown in the figure. The effect of this management tool is that, unless a company can earn a desired return after tax on its investments (12 to 15 percent, for example), it will elect not to enter into such investments.

Based on this viability threshold, it is shown that the 3000 and 4000 foot field length airplanes reached a high level of return on investment and have the potential for long term economic viability. The 100 passenger and 2000 foot field length airplanes either fell below or barely reached this viability threshold.

5.2.2 Finance

5.2.2.1 Chicago Region - Typical activities are summarized below.

5.2.2.1.1 Background - Service in the Chicago region STOL system was assumed to begin with a fleet of nineteen E 150.3000 systems analysis aircraft delivered over the first year. The route structure would grow over the next six years reaching maturity in the seventh year of operation. The initial fleet increased from nineteen to thirty-eight aircraft. Operations in this region were conducted by an autonomous subsidiary of an existing airline. Initial financing was provided by the parent company.

5.2.2.1.2 Initial Financial Parameters - Chicago region operations and financial results are traced over the first 10 years, 5/6 of the life of the first group of STOL aircraft delivered. This "planning horizon" was chosen to simplify the matter of second generation STOL aircraft selection and introduction.

RETURN ON INVESTMENT - DISCOUNTED CASH FLOW

REPRESENTATIVE REGION (CHICAGO)

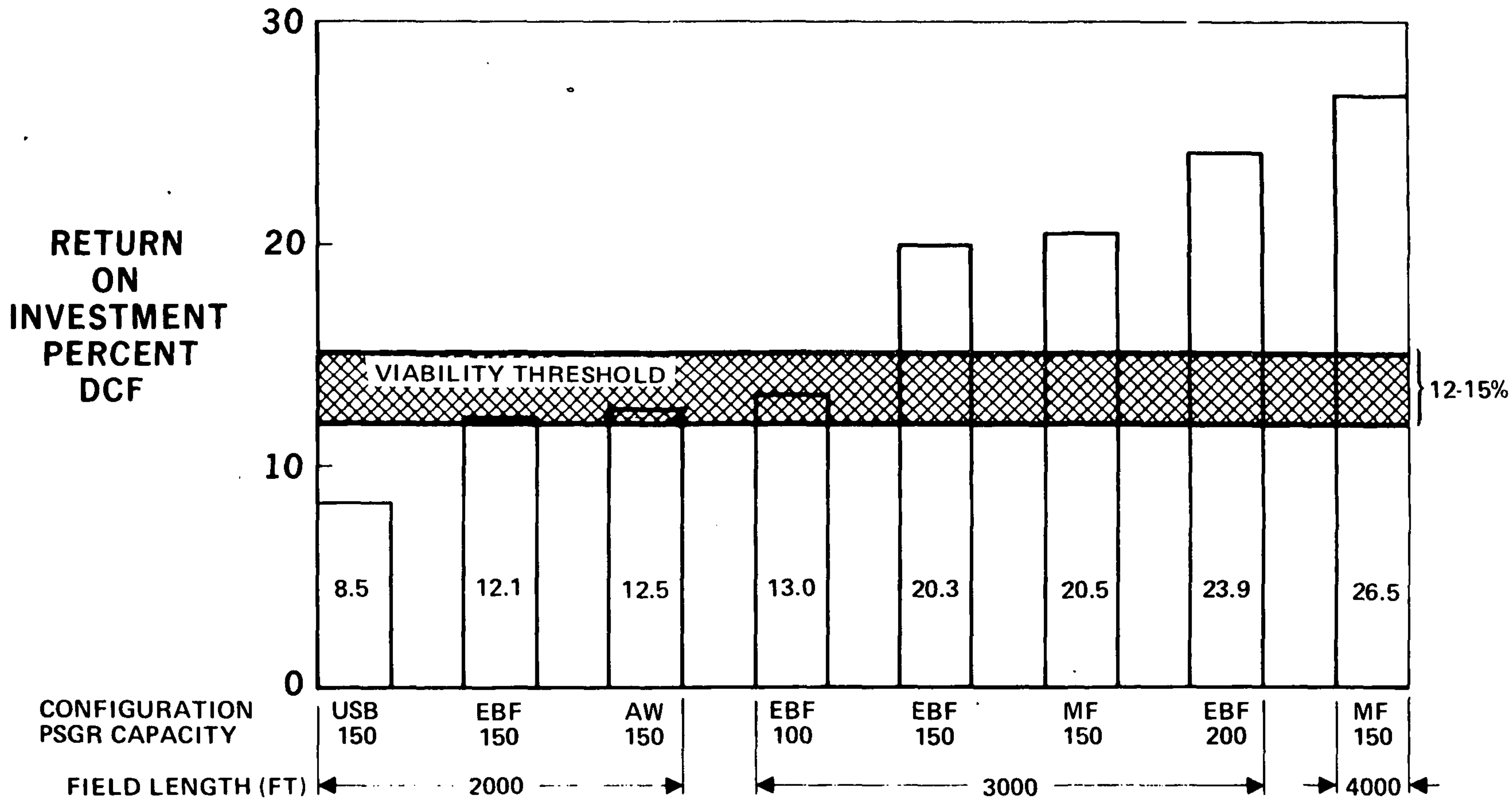


FIGURE 5-5

The primary analysis focused upon a feasible financial structure based on a combined long term debt and equity to operating assets ratio of 1.14, $220 million equity and $330 million long term debt versus $482.9 million of operating assets - aircraft, spares, ground equipment and facilities. The initial debt/equity ratio was 1.5. This changed through time as early losses are compensated by later profits. The initial interest rate of 8.5% was chosen to be representative of long term interest rates for pioneering operations in the airline industry. The financial results were simulated without debt retirement although partial retirement can be observed by examing airline operating history.

5.2.2.1.3 <u>Initial Operating Parameters</u> - The revenue computations for the detailed analysis were based on the CAB Phase 7 fares without yield dilution to simplify the problem. The average load factor used in the analyses was 60 percent. The aircraft operate over a 12 city-pair network achieving a 7.6 hour per day utilization. The Chicago network and STOL maneuver time estimates provide an average block speed of 351 s.m. per hour (565 km/hour) over the 319 s.m. (512 km) average stage length. The average stage length provides a direct operating cost of $2.51 per aircraft mile ($1.56 per aircraft kilometer).

5.2.2.1.5 <u>10 Year Income Statement</u> - Annual revenues increase from $60 million during the first years of operation to $339.5 million during the 10th year. At that point the system would be carrying 10.5 million passengers per year. The direct operating expenses increase from $23 million during the first years, when an average of 9.5 aircraft were operating, to a level of $92.9 million in the sixth year. Depreciation increases as the fleet expands to 38 aircraft during the first five years. Indirect costs increase with systems development but at a slower rate. The combination of increasing load factors, expanding

routes and system maturation lead to a steady improvement in operating income from a negative $2.5 million to a plateau of about $98 million in the seventh year. Interest expense is constant over the period because the long term debt was assumed to be refinanced at or before maturity. Accelerated depreciation shelters operating profits and conserves cash flow during the formative years rising to $34 million per annum in the 9th year. The non-perturbed simulation forecasts very optimistic profit results commencing the fourth year.

5.3 Total System Costs

This section focuses upon the total implications as seen by various users and participants in STOL systems development and operations. The STOL system affects many more segments of the economy than is commonly realized. Table 5-4 shows these effects in terms of investments and operations on a national level. Assets of the public and private sectors (airlines) are further delineated on a regional basis in Tables 5-5 and 5-6. The Chicago Region was used as a basis for developing a polar plot and exhibiting a gross transaction flow of the 10-year accumulated results as shown in Table 5-7. The gross transactions accounted for by the short-haul economic model illustrates the many interfaces and economic complexity of implementing a domestic STOL system. The total system cost is perceived from many viewpoints. As shown in Table 5-4, the traveling public expends $20.0 billion over the 10 years, the aerospace industry receives $6.6 billion, the financial community invests $3.4 billion and the government sectors invest $357 million. When the interactions are considered even these "costs" change.

TABLE 5-4

THE COSTS OF THE DOMESTIC STOL SYSTEM FOR EACH SEGMENT OF THE ECONOMY

(10 YEAR PERIOD)

DOLLARS - MILLIONS

	INVESTMENT	OPERATIONS	TOTAL
TRAVELING PUBLIC	—	19,769.4	19,769.4
FEDERAL GOVERNMENT	155.7	173.4	329.1
LESS RECEIPTS - TAXES	—	*3,482.6	*3,482.6
TOTAL	155.7	3,309.2 CR**	3,153.5 CR
LOCAL GOVERNMENT	201.9	629.0	830.9
LESS RECEIPTS	—	*1,381.6	*1,381.6
TOTAL	201.9	752.6 CR	550.7 CR
AEROSPACE INDUSTRY	—	*6,623.3	*6,623.3
CONSTRUCTION INDUSTRY	—	* 307.5	* 307.5
FINANCIAL COMMUNITY - DEBT	2,044.3	*1,695.0	349.3
- EQUITY	1,362.8	* 681.4	681.4
TOTAL	3,407.1	2,376.4	1,030.7
DOMESTIC AIRLINE INDUSTRY	2,991.1	13,776.6	16,767.7
LESS RECEIPTS	—	*17,687.6	*17,687.6
TOTAL	2,991.1	3,911.0 CR	919.9 CR
FOREIGN AIRLINE INDUSTRY	2,037.2	578.1	2,615.3

* RECEIPTS
** CREDIT

TABLE 5-5

PUBLIC SECTOR FIXED ASSETS

(10 YEAR PERIOD)

REGION	LOCAL OR COMMUNITY	FEDERAL		TOTAL
		ADAP	FAA	
CHICAGO	33,318,000	7,587,000	20,868,000	61,773,000
CALIFORNIA	52,849,500	12,569,500	21,028,000	86,447,000
NORTHEAST	42,009,500	10,509,500	10,255,000	62,774,000
NORTHWEST	5,121,000	1,340,000	5,128,000	11,589,000
SOUTHEAST	44,273,000	11,720,000	25,333,000	81,326,000
SOUTHERN	24,355,000	6,050,000	18,326,000	48,731,000
TOTAL	201,926,000	49,776,000	105,938,000	352,640,000

TABLE 5-6
PRIVATE SECTOR (AIRLINE) OPERATING ASSETS
(10 YEAR PERIOD)

REGION	DOLLARS IN MILLIONS				TOTAL
	AIRPLANES[1)]	SPARES	EQUIPMENTS	FACILITIES	
Chicago	430	37	6	10	483
California	589	48	7	11	655
Northeast	645	51	7	10	713
Northwest	79	11	3	4	98
Southeast	657	52	9	9	727
Southern	272	27	5	12	315
Total	2,672	226	37	56	2,991

1) Based on 236 systems analysis airplanes (150 passenger, 3000 foot field length, externally blown flap).

DOMESTIC STOL SYSTEM GROSS TRANSACTIONS E150.3000 BASELINE AIRPLANE –
10 YEARS OPERATIONS – 6 REGIONS – 1972 DOLLARS – MILLIONS

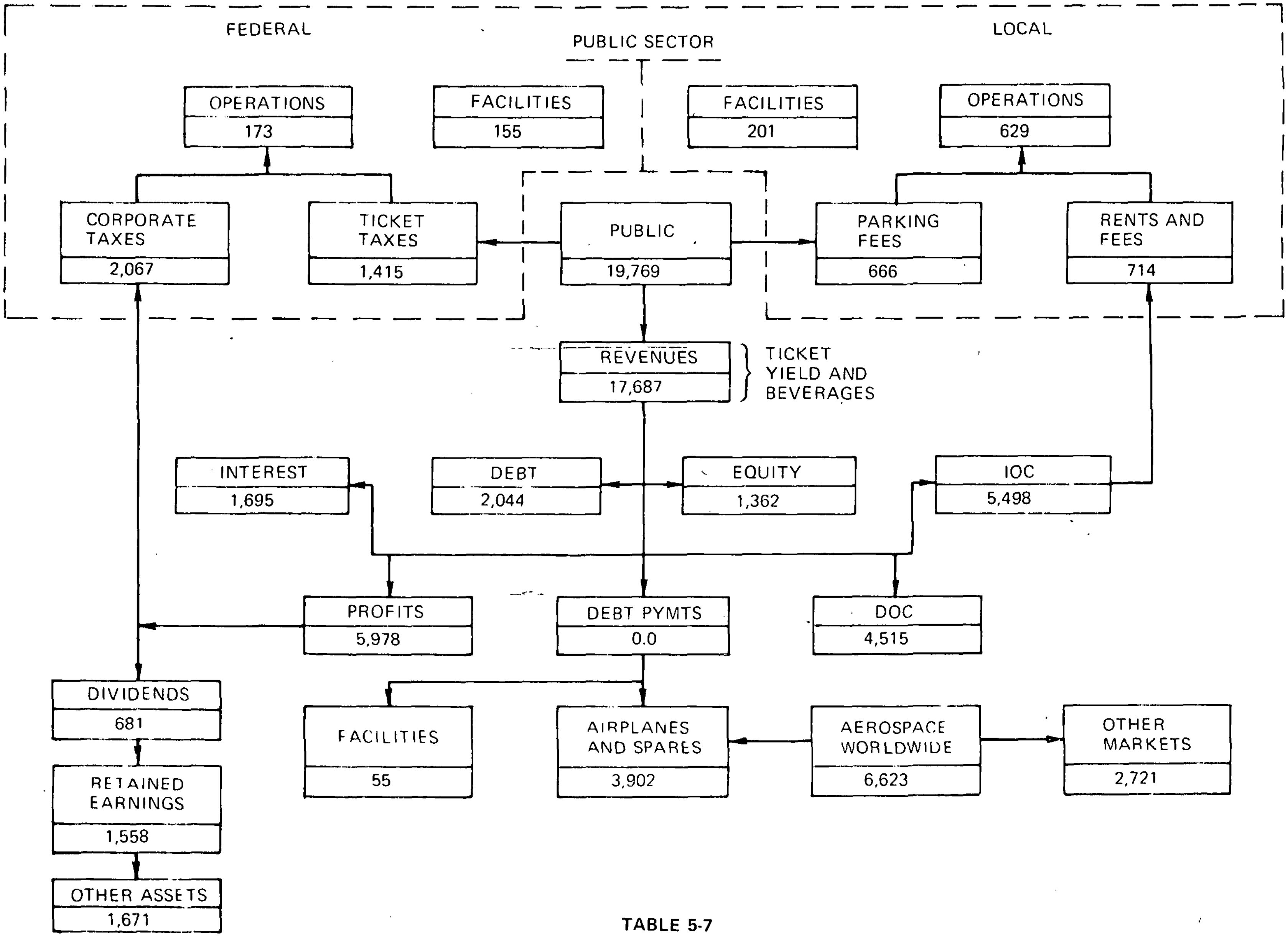


TABLE 5-7

6.0 SYSTEMS ANALYSIS

Phase I activities consisted of the development of the approach and methodologies for analytic and tradeoff studies of parametric aircraft and the evaluation of their performance in simulated regional airlines. Phase II activities integrated these efforts in the evaluation of aircraft and operating systems for simulated airlines in each of the six main geographic regions of the United States.

The basic study approach, consistent with the study integration shown in Figure 6-1, is divided into five (5) discipline areas. The role of each is summarized briefly.

- o Market Analysis - provide estimates of the passenger demand for short-haul air travel in the 1980-1990 period.
- o Airport Analysis - select and evaluate the suitability of strategically located airports from which regional airline operations may be simulated.
- o Aircraft Analysis - determine the characteristics of candidate STOL aircraft.
- o Economic Analysis - evaluate cost and profitability of each aircraft concept.
- o Systems Analysis - create the framework and methodology to integrate the study.
    - Operations Analysis - integrate aircraft and airports into simulated regional airlines with travel demand providing quantification.

STOL SYSTEMS STUDY INTEGRATION

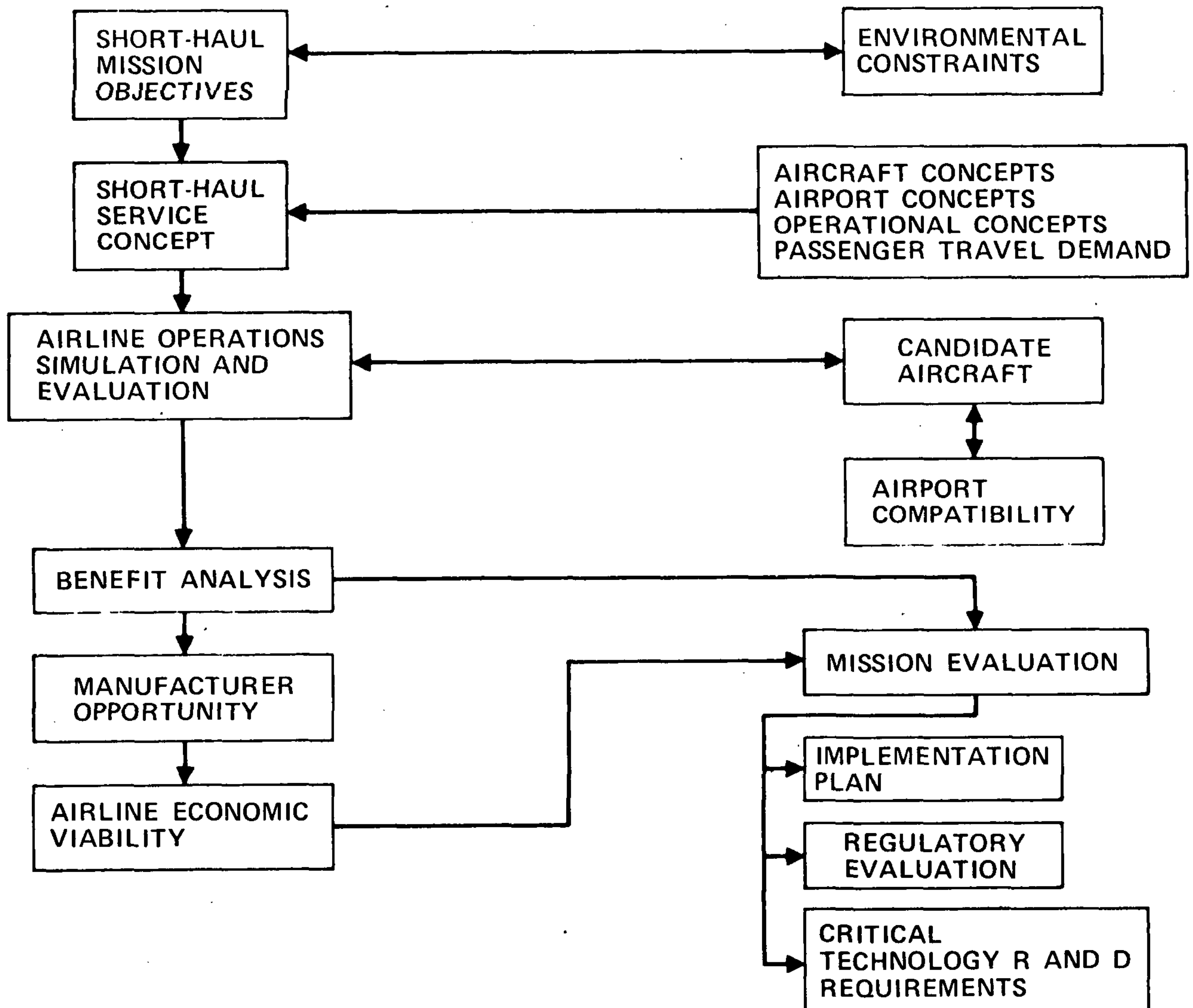


FIGURE 6-1

PR3-STOL-1510

A set of general criteria for evaluation and selection of short haul air transportation systems includes the following:

- o Services provided to the traveler:
  - . Minimum door-to-door travel time enhanced by the quiet aircraft characteristics and site accessibility of the airport.
  - . Competitive fare levels with respect to CTOL and advanced surface systems.
  - . Acceptable comfort levels.
  - . Convenient departure/arrival schedules.
- o Community acceptance of the service at existing and new sites:
  - . Tolerable noise and exhaust emission levels.
  - . Acceptable total and peak hour distributions of air traffic.
- o Acceptable increases in the flow and location of surface vehicle traffic.

The material which follows is a general description of the activities shown in Figure 6-1.

In past design of commercial aircraft, the manufacturers and airlines have produced vehicles to satisfy technical, performance and economic requirements. Contemporary and future designs are being subjected to environmental and ecological pressures. Consequently, future aircraft, such as a proposed STOL, must be designed to fit the airport and the community environment as well as the above requirements.

Environmental constraints are dominant considerations in planning and designing future air transportation systems. Thus, short-haul mission objectives must be specified within the environment of the operational period. A service concept reflects supply and demand balancing in creating a system of airports, aircraft, and air operations concept to provide travelers with satisfactory service. Integrating these elements in a simulated regional airline permits evaluation of the elements, shows how changes could improve the operation, and achieves quantitative results which describe the performance of the system.

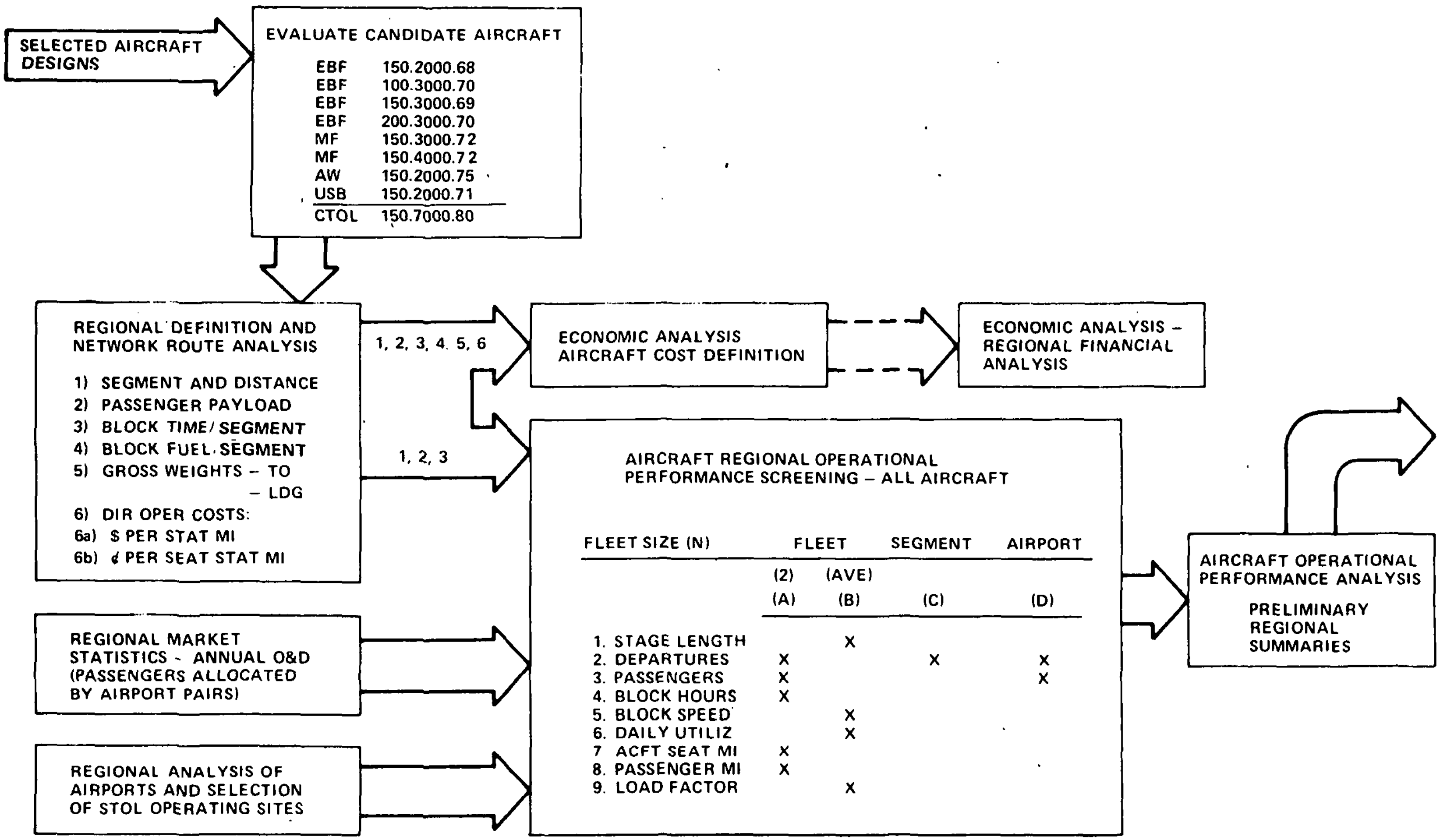
A benefit analysis of the quantitative data provides a basis for a realistic assessment of the aircraft concepts and requirements. From this data, estimates of profitability for the manufacturer are determined. With the addition of facilities and supporting equipment, airline profitability may be estimated. If all these evaluations are favorable, the system is evaluated against the original mission objectives to determine performance. Although not shown in Figure 6-1, iteration of any step in the systems study facilitates changes in assumptions to improve the system.

With the achievement of a satisfactory system, the remaining steps can be taken to develop an implementation plan and to identify research and development areas required for the successful implementation of a STOL transportation system.

6.1 Aircraft/Systems Evaluation

A detailed outline of the manner of accomplishing the system analysis procedure is presented in Figure 6-2, STOL Aircraft/System Evaluation.

STOL AIRCRAFT/SYSTEM EVALUATION

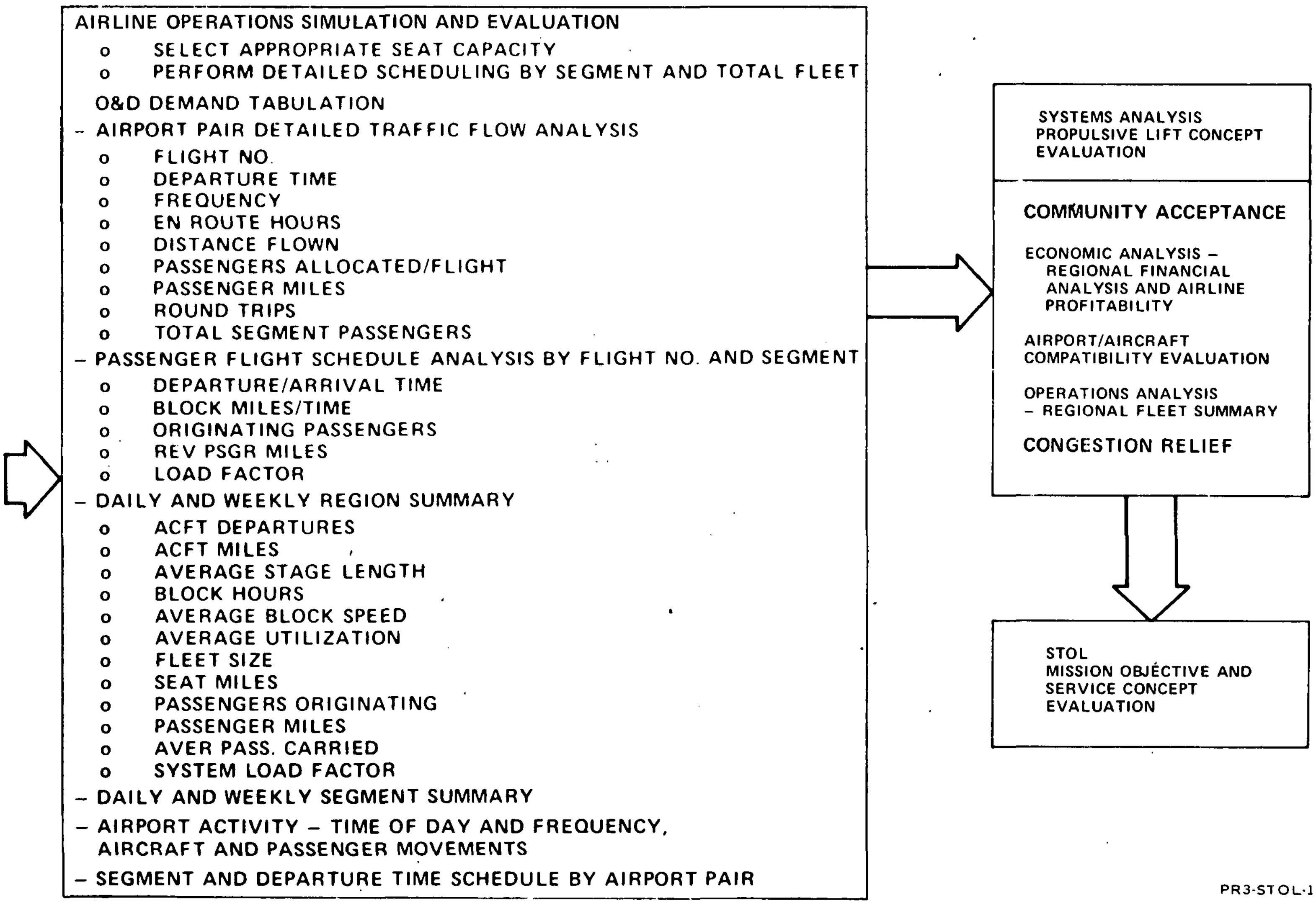


FLEET SIZE (N)	FLEET (2) (A)	FLEET (AVE) (B)	SEGMENT (C)	AIRPORT (D)
1. STAGE LENGTH		X		
2. DEPARTURES	X		X	X
3. PASSENGERS	X			X
4. BLOCK HOURS	X			
5. BLOCK SPEED		X		
6. DAILY UTILIZ		X		
7 ACFT SEAT MI	X			
8. PASSENGER MI	X			
9. LOAD FACTOR		X		

FIGURE 6-2

PR3-STOL-1592 A

STOL AIRCRAFT/SYSTEM EVALUATION
(CONTINUED)



PR3-STOL-1593A

FIGURE 6-2 (CONT)

The flow is self-explanatory, the primary function being to show specific parameters used in the system design and analysis. Environmental and other external data are established as noise and pollution limits, airport locations with respect to a quantified travel demand, existing dimensions of the airports and routes between them, and trend variations of travel demand with time.

Derived data consists of the aircraft characteristics, changes to airports, and output data describing the performance of the system. Each of these is indicated in appropriate boxes in Figure 6-2.

In addition to the key points shown, a target of 20 percent relief of CTOL congestion was used for the STOL scenario and system evaluation. Key operations scenario highlights are presented below.

- o Continental U.S. divided into six geographic regions with airline routes having stage lengths of 600 statute miles or less.
- o STOL and CTOL air traffic planned to operate from separate runways.
- o Choice of STOL sites based on relief of constraints at hub airports.
- o STOL service planned to operate within community environmental restraints.
- o Airline realism provided in scheduling, basing and maintenance concepts.
- o The study approach utilized the EBF 150 . 3000 aircraft for baseline systems analysis and evaluation.

Within the scope of the study, the 3000 foot (915 m) field length concepts are preferred in comparison with the 2000 foot (610 m) concepts considering direct operating cost, fuel consumption and maintenance. For example, a 2000 foot (610 m) field length capability, in comparison with 3000 foot field length, results in a penalty to the EBF design of 39 percent in fuel burned and 28 percent in DOC. The 150 passenger capacity aircraft is the best compromise of the four sizes studied (50, 100, 150, and 200).

Introducing a STOL system in high density markets, using STOL runways on existing air carrier airports, will provide noise relief by the replacement of noisey CTOL aircraft and should result in relatively few community acceptance problems. Introducing a STOL system at existing general aviation airports will, in most instances, result in increased ground traffic and inconvenience to general aviation activities. These concerns will require special attention. The introduction of a STOL system into a non-aviation precedent area will most likely face strong community opposition.

The implementation of a STOL system is dependent on incorporation of the necessary airport, ATC, runway, terminal, and access improvements on a timely basis. The basic technical capabilities to be developed in the FAA's currently planned R&D program in support of air traffic control for CTOL operations are considered adequate to support STOL operations. Microwave ILS equipment is needed to support STOL operations in addition to normal CTOL ATC equipment.

The United States civil STOL market in 1985 is estimated to be 426 aircraft (one hundred fifty passenger payload). This forecast is based

on fleet evaluation and scheduling analyses conducted for the 494 high, medium and lower density city pairs in all seven regions.

The aircraft quantity varied from 125 for the Northeast region, which is comprised of numerous hign density markets, to 13 for the Northwest region which is mostly comprised of medium and low density city pairs. The distribution of fleet requirements by region is shown below.

U.S. CIVIL STOL MARKET - 1985

High, Medium, Lower-Density Markets

(494 City Pairs)

Region	150 Passenger Aircraft
Chicago	98
Northeast	125
California	57
Southeast	76
Southern	39
Northwest	13
Hawaii	18
Total	426

The study revealed no significant technical aircraft problems nor any outstanding system facilities or operating problems that could not be solved within the time frame prior to the 1982-83 implementation period. Implementation of the airport network, however, will need special attention since the airports are under local community jurisdiction. An extensive

public education program is needed to assist in gaining community acceptance of airport activities related to STOL operations.

6.2 STOL System Implementation Plan

The nation's economic strength is linked directly to its transportation system. A highly developed, productive and expanded transportation system is a priority requirement to support the two and one-quarter trillion dollar economy forecast for 1985. This growth is dependent upon a technologically advanced and integrated transportation system. A short-haul air transportation system must be considered as an integral part of the required transportation system expansion.

New conventional air carrier airports, as a means of increasing the capacity of the nation's air transportation system, will require huge expenditures of money, vast areas of land, environmental clearances and many years from the planning stage to actual construction and operation. In addition, the costs, environmental clearances and plans for developing the access connecting the new airport to the local ground transportation network will add more years before the total system could be implemented.

A new short-haul air transportation system will prolong the life of existing conventional airports as well as increasing operational efficiency.

The timely implementation of the proposed short-haul system is directly dependent on two pacing development areas - the airport and the engine technology. Both government agencies and private industry are participating in the development of a STOL system. NASA is taking a leading

role in the development of the needed STOL technology. The DOT is participating in system requirements. The FAA's role in airport development is well-defined. The CAB has been holding hearings on STOL service for some time. However, for industry to commit large expenditures required to build and implement such a system, the expansion of the government's role in sponsoring technological development will have to be accelerated.

The implementation of a STOL system is coupled to three principal requirements: engine development, airport activation and aircraft development as a consequence of airline commitments (Figure 6-3). Assuming that NASA proceeds in mid-1973 with the research and development of a quiet-clean engine, the program should provide data leading to the production of commercial STOL engines in the 1979-80 period. This would permit the development of STOL aircraft to commence in mid-1977 with production deliveries beginning in the 1981-82 period. Environmental approval could be initiated in the latter part of 1973 for the necessary airports. Construction and activation would occur during the period beginning with 1979. These elements brought together in the proper combination could lead to STOL service implementation in the 1982-83 period.

A number of pacing factors exist in the implementation of a STOL system. The airport program is the most time-consuming in the schedule. Environmental impact statements are required for all new construction projects including new airports and changes to airports as well as a host of other public and private projects. An aircraft and engine development program must be integrated with airport development. A system integration approach is mandatory on a national scale to develop, initiate and fully implement a

STOL SYSTEM IMPLEMENTATION

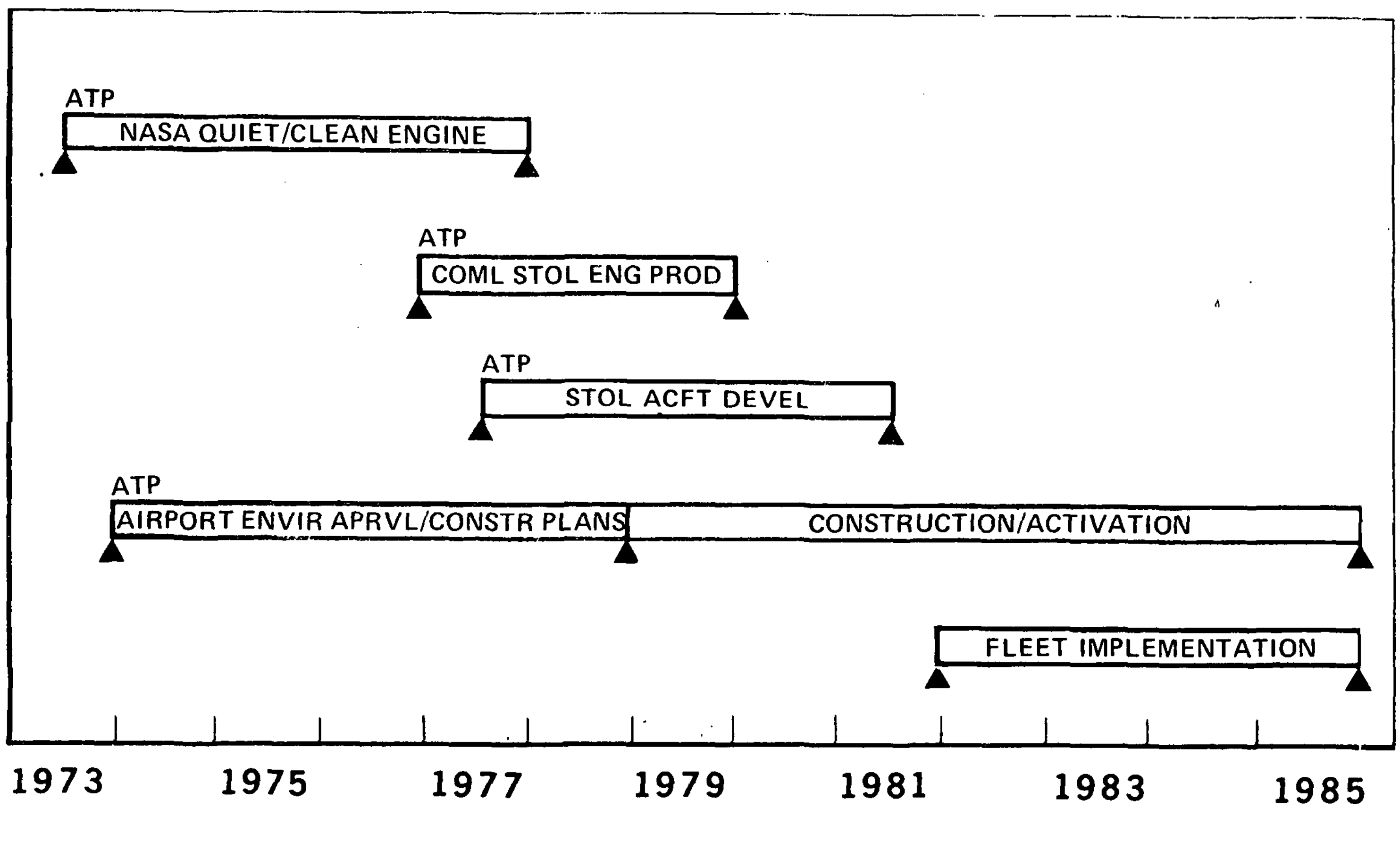


FIGURE 6-3

national STOL transportation system. A number of key pacing factors are notable in the development of an implementation plan and schedule. These are:

- o Quiet/clean engine
- o Airport availability
- o Community acceptance
- o Airline/manufacturer commitment
- o Financial commitment
- o Air traffic control requirements
- o Regulatory commitment

7.0 AIRLINE PARTICIPATION

To assist Douglas in conducting the STOL Systems Study, a carefully selected and balanced team of airline subcontractors was established (Air California,Allegheny, American and United).

Air California is an innovative intrastate operator providing service between major and large secondary terminals within the California Corridor.

Allegheny Airlines has extensive experience with high, medium and lower density short-haul operations in the Eastern and mid-Western portion of the United States including the Northeast Corridor.

American Airlines has conducted numerous studies of STOL aircraft and systems. They include development ofrequirements for a commercial STOL transport and STOLports. American conducts extensive operations in the Northeast Corridor.

United Air Lines has extensive high, medium and lower density short-haul operations throughout the United States including the very high density and competitive California Corridor.

The airlines' efforts included:

(1) Continuous assessment of the Douglas efforts to assure commercial airline realism.

(2) Assistance in carrying out special aspects of the study.

Detailed working reviews were held with all the airlines at

key study milestones to assure that the study continuously reflected real world airline economic, operating and marketing considerations. In addition to the working sessions, selected airlines were given special tasks to carry out.

The study results reflect and were influenced by the inputs of the airline subcontractors. The significant airline inputs are outlined below. These as well as other airline contributions to the study are outlined in other volumes of the Final Report.

Aircraft

- It is believed technically possible to certify the STOL aircraft with a flight crew of two.
- STOL aircraft must have unusually high reliability because of their economic vulnerability to other modes of transportation in the event of excessive delay.
- A strong preference has been expressed for low wing STOL aircraft. This is primarily motivated by ditching requirements and passenger appeal considerations.

Airports

- All airline subcontractors agreed that for a totally meaningful assessment of the **operational aspects and**

viability of short haul STOL, specific determinations must be made of the capability for achieving independent, non-conflicting operation of STOL and CTOL aircraft (airspace and airfield ground side) at those high density airports presently or potentially congested.

- The addition of special STOL runways and navigation facilities at major CTOL airports are not favored as they will increase landing fees.

Markets

- The aircraft should have a capacity of 150 passengers or greater.
- Four flights per day should be the minimum frequency between high density city-pairs.
- New STOLports probably will not win community acceptance in the foreseeable future.
- Reviewed and suggested changes to the modal split methodology.

Economics

- Total operating cost, not direct operating cost, is one of the preferred means for evaluating STOL economics.
- Cost-generated fares are not realistic.

Systems Analysis

- CAT IIIA is not expected to be cost effective
- A 95 EPNdB sideline noise level at 500 feet is unrealistically

low for STOL aircraft operations from present commercial airports. Attention should be shifted from the 500 foot sideline criteria to the takeoff criteria where the community noise problem exists.

- The indirect costs for STOL short-haul operations cannot be reduced below those for CTOL short-haul.

7.1 Study Constraints

The airline subcontractors believe the study did not reflect commercial airline realism in some areas due to certain guidelines and assumptions in the basic Statement of Work.

- The need to reduce noise should be stressed rather than the emphasis placed on congestion during the 1980-1985 time period. The airline subcontractors believe that although there will be congestion in the air and on the ground, the impact of congestion was being over-rated.

- The requirement for Category IIIA operational capability is not cost-effective.

- The noise requirement of 95 EPNdB at a sideline distance of 500 feet placed unrealistic restrictions on the aircraft designs.

8.0 CRITICAL TECHNOLOGY AREAS

One of the objectives of the STOL Systems Study was to identify the critical technology areas where additional research and development is required. These areas include acoustics, propulsion, aerodynamics, structures and materials, ice protection, and airports and operations.

8.1 Acoustics

8.1.1 Noise Design Criteria. - The major technical problem facing the air transportation industry is aircraft noise. The most widely used aircraft community-noise design criterion available today is Part 36 of the FAR with the effective perceived noise level (EPNdB) as the noise-rating scale. While this criterion is clearly an improvement over the previous situation, new criteria are foreseen for future STOL airplanes to serve a new short-haul market. Present certification noise standards for transport aircraft do not take into account community acceptance factors, such as, the psychoacoustics - the characteristics and the duration and time frequency of the noise source. The present three-point measuring system may be acceptable, however, the distances where noise is measured or the allowable levels of noise may be unrealistic for future short-haul STOL aircraft operating from airports near population centers. The present measuring points are relevent to long-haul airports only.

- Research is required to establish proper noise-rating scales and noise-measurement locations to ensure minimum negative community reaction and to permit more accurate evaluation of alternative aircraft designs. The research should include laboratory and operational evaluation, tests and social surveys with the goal of establishing a set of realistic standards that can be used as

aircraft design criteria. This research is urgently needed for environmental planning relative to airports in land use planning, for legal decisions by the courts, for conducting aircraft design trade studies by the manufacturers, and by the airlines to evaluate the impact of operational procedures.

8.1.2 Noise of Powered-Lift Systems. - For airplanes that generate propulsive lift by blowing on, over, or through the wing and flap surfaces, significant noise is generated by mechanisms that today are poorly understood. No effective, economically feasible method has been developed to achieve substantial reductions in any of these sources of noise. Preliminary indications are that a large amount of suppression may well be needed to achieve acceptable community noise levels.

- Laboratory and large scale tests (static and flyover) are required to identify sources of noise, their directivity patterns under and to the side of the flight paths, and to develop economically viable suppression systems.

8.1.3 Far-Field Aerodynamic Noise. - Aerodynamic noise associated with the airflow over the various surfaces of an airplane (wing and flaps, fuselage, and tail surfaces) may be an important contributor to the noise levels measured beneath the takeoff and approach flight paths.

- Flyover noise tests using various aircraft need to be conducted to evaluate the magnitude of this airframe-generated noise as a function of pertinent aircraft parameters and to correlate the results with analytical models of the noise generating mechanism.

- Based on the results of these flight tests and other tests and analyses, a technique needs to be developed to permit reliable estimates of the level of airframe-generated noise for various types of high-lift systems, wing planforms and cross sections, airplane attitudes, and configurations and flap deflections.

8.2 Propulsion System

8.2.1 Propulsion Technology Advancement. - The various lift concepts have different technology advancement requirements. Table 8-1 is a summary of the propulsion technology advancements required for each lift concept. General improvements such as lighter, quieter engines that are beneficial to all transport aircraft are not identified here.

All of the lift concepts except the externally blown flap favor turbomachinery essentially similar to existing turbofan engines but with quieter fans. The externally blown flap, however, shows performance improvements by the use of a variable pitch fan engine. (This type of engine might also be used to advantage on a four-engine mechanical flap aircraft). A variable pitch fan engine has been developed for low thrust and low fan pressure ratio by the Europeans. Model fan testing has been conducted in the U.S.

- Technology advancement is required to establish the capability to produce reliable variable pitch fan engines of the thrust level required for short haul transport aircraft. Together with the need to advance the technology is the requirement to demonstrate that a variable pitch fan will perform as intended with flight weight hardware. Such a demonstration is required before such an engine would be committed to production.

TABLE 8-1

SUMMARY OF AREAS REQUIRING

PROPULSION TECHNOLOGY ADVANCEMENT

LIFT CONCEPT	ENGINE	INSTALLATION
Augmentor wing	o Present Technology Appears Adequate	o Wing Flow Ducting o Engine to Wing Flow Diverter Valves o Thrust Reverser
Mechanical Flap	o Can Use Same Engine As EBF	o Thrust Reverser
Upper Surface Blowing	o Can Use Same Engine As EBF	o Variable Area Nozzle o Thrust Reverser
Externally Blown Flap	o Variable Pitch Fan o Moderate Tip Speed vs Gears	o Variable Area Nozzle

- In the design of a variable pitch fan engine, an option exists between using a moderate fan tip speed that allows the use of a direct drive; or a low tip speed, with higher fan loading, that favors the use of gears. For the design noise level of 95 to 100 EPNdB, the higher tip speeds require the absorption of multiple pure tone noise. The choice between this type of design and the lower tip speed fan with gears should be further assessed.

- All the lift concepts require technology advancement directed towards improved installation of engines in the airframes. The augmentor wing requires technology advancement in order to be able to design the wing flow ducting with its multiplicity of discharge slots to assure the necessary level of noise reduction. Since the wing nozzles have a large perimeter to flow area ratio, the means for engine matching needs to be established. The effects of thermal expansion, duct pressure and wing deflections on overall system performance must be determined. The augmentor wing also needs a flow diverter valve for transition between the powered lift and cruise modes. The valve must maintain its functional position in the event of an actuation system failure. Pressure losses need to be minimized and inspection and maintenance provisions included.

8.2.2 Thrust Reversers - All concepts require advancement in engine installation technology to achieve effective thrust reversing. A variable pitch engine installation requires a fan nozzle which has a different exit area at takeoff than at cruise, and also functions as an inlet in the reverse thrust mode. The fixed pitch engines require improved low speed reversing capabilities. This improvement means reverse flow directional

control to minimize re-ingestion and ground impingement. Each lift concept requires a reverser configuration tailored to the installation.

- The augmentor wing uses an engine with a bypass ratio of 2.8 and has a takeoff thrust to gross weight ratio of about 0.4. With only fan flow reversing, and an effectiveness of 50%, the static reverse thrust to aircraft gross weight would be only 10%. This combination of a relatively low bypass ratio and aircraft thrust loading thus results in the need for both fan and primary flow reversers with a high degree of efflux directional control.

- The augmentor wing fan reverser requires a forward thrust flow blocker which may be remote from the reverser cascades. This flow blocker must be synchronized with the reverser cascade covers.

- The mechanical flap aircraft with a fixed pitch fan engine requires a fan thrust reverser similar to present CTOL concepts augmented by the need to have improved low speed capabilities for minimum re-ingestion and flow ground impingement.

The upper surface blowing lift concept can use either a fan-only thrust reverser or a reverser in the common fan and primary duct section. A fan-only reverser could be similar to that required for the mechanical flap aircraft. A common-duct reverser was selected in this study since a variable area nozzle, which is required, can also function as a reverser/flow diverter. Although common-nozzle reversers are in existence, present designs are not suitable for operation below 60 knots, and the possibility of combining the thrust reverser and variable area nozzle appears attractive for the USB installation.

- Further development is required of the best means of thrust reversing for the USB concept and the possibility of combining the reverser with a variable area nozzle.

8.2.3 Variable Area Nozzles. - According to available NASA data, in addition to the need for area variation to change the engine match between takeoff and cruise for the USB concept, the flow must be deflected downward to stay attached to the wing during the propulsive lift mode.

- Further exploration is required to identify nozzle design constraints such as nozzle exit plane aspect ratio and nozzle height to flap chord requirements.

The high bypass ratio variable pitch fan engine for the externally blown flap aircraft requires a variable area nozzle to change the engine match between takeoff and cruise. In addition, this variable area nozzle could open and function as an inlet in the reverse thrust mode. Current fixed-area nozzles are designed to maintain a fairly constant discharge coefficient, to obtain good cruise performance.

- The variable area feature of the high bypass ratio engine permits a more flexible approach to nozzle design. The means of using this to advantage requires exploration.

8.2.4 Engine Cycle Selection vs. Noise. - Recent investigations such as that reported in AIAA Paper No. 73-5 indicate airframe generated noise levels without any engine noise may be in the order of FAR Part 36 less 8 or 10 EPNdB units. It is, therefore, possible that reducing engine noise levels to 95 EPNdB on a 500 ft. sideline may result in airplane "signature" noise dominated by the airframe.

- The influence of higher noise level goals on the engine cycle selection should be investigated. The trade study conducted in this contract effort compared three engines with three levels of sound treatment, resulting in nine aircraft. The effect of increasing field length and noise level concurrently was not done. Further, inasmuch as the airframe noise floor measured on a sideline is dependent on the flap configuration and flight attitudes, the combined effect of changing the engine cycle and the flight operational techniques should be investigated.

8.2.5 Emissions. - The presence of irritating oxidants in the urban atmosphere has been ascribed to the interaction of hydrocarbons (HC) and nitrogen oxides (NOX) in the presence of sunlight. It may be easier to reduce emissions of hydrocarbons than NOX, and such action may be sufficient to reduce smog irritants. Aircraft operation add a very minor amount of pollutants to the atmosphere and this occurs mostly during ground operations and while flying at low altitudes.

- Additional studies should be made to determine the impact of NOX on the environment, in the presence of varying amounts of reactive hydrocarbons. Engine combustor design, and research and development, should be continued on a high priority basis directed toward the reduction of all harmful jet engine emissions. Special emphasis should be placed on the reduction of nitrogen oxides. One possible way to control NOX emissions is to restrict the cycle pressure ratio of the engines. However, restricting the pressure ratio below that required by other considerations will have a serious impact on the performance of the airplane and, therefore, the direct operating

costs. A study should be made to assess direct operating cost as a function of NOX control by pressure ratio variations.

8.3 Aerodynamics

8.3.1 Ground Effect. - Accurate knowledge of the ground effects during take-off and landing has a major impact on the design of propulsive high-lift systems.

- Additional research is required to determine the influence of ground effect on the landing flare maneuver, the use of direct lift control systems, the margin of approach speed to stall speed, and available load factor required for commercial operations. The aircraft with shorter design field lengths tend to be more sensitive to ground effects since their design wing loadings are limited by landing performance. These aircraft tend toward lower wing loadings.

There are weight and cost penalties associated with low wing loadings, and ride quality is only marginal in turbulent air.

- Research is required to develop improved systems for gust alleviation and ride comfort which might also allow reduction in structural strength margins and aircraft weight empty.

At present, no upper surface blowing (USB) high lift aerodynamic wind tunnel data in ground effect are available.

- Test information is needed pertaining to the stability of the USB Coanda turning process in ground effect and in the dynamic ground effect maneuver.

8.3.2 Upper Surface Blowing. - The USB propulsive lift concept is relatively

new and does not have the same data base as other high lift configurations.

- o Investigations are required to define nozzle shapes, chordwise nozzle positions and Coanda flow turning relationships which produce acceptable low cruise thrust scrubbing losses and good high-lift characteristics at low noise levels. Boundary layer control on the trailing edge flap may be useful for helping to achieve high turning angles necessary for landing. Chordwise fences used on the cambered upper surface of the wing/flap may help to achieve a more two-dimensional Coanda flow with resulting higher turning efficiencies.

- o USB wash effects on the empennage, with all engines operating and with one engine out, should be evaluated.

- o Both chordwise and spanwise BLC on the leading edge should be investigated for achieving high $C_{L_{MAX}}$ values.

8.3.3 Hybrid Configurations.

- o Hybrid configurations using a combination of high lift concepts should be investigated. For example, as stated in the previous section, the USB with blowing on the trailing edge flap is essentially a combination of USB with the jet flap principle. This hybrid could possibly produce high turning efficiencies.

- o Canard configurations could offer advantages in longitudinal trim and maneuvering capability. Control configured vehicles utilizing a combination of controls such as wing flaps and canards might prove very efficient. Studies should be made to determine whether canard and multiple control systems can be coupled mechanically or

electronically to achieve longitudinal control throughout the aircraft lift range. Canard-wing position and various planform studies are necessary to determine configurations with acceptable canard - wing interference effects. Use of sensors and electronically-activated flaps, canard surfaces, elevators, and engine thrust may be a means to provide the highest possible climb rate to minimize climb-out noise footprints.

8.4 Structures and Materials

Reduction of structural weight through the applications of new emerging materials has the greatest potential for improvement of system economics, as demonstrated in Reference 1. The weight saving potential of advanced composites is significantly greater than that of other materials, as discussed in the Structures and Materials section of that report. As discussed in Reference 2, principal barriers to extensive application of advanced composites to aircraft structures are high costs and lack of experience for broad applications to primary structure.

The validation of advanced composites requires substantial attention to promote acceptability, both to manufacturers and airlines. This validation will require implementation of a wide range of programs that develop a large amount of production and operating experience. Expected payoffs for this technology application include reduced weight, improved manufacturability, and increased reliability through improved fatigue behavior.

References

1. Douglas Aircraft Co., "Advanced Transport Technology Economic Evaluation", NASA Contract NAS1-10705

2. Anon, "Panel Reports of Composites Recast, An Air Force/NASA Long Range Planning Study", 22 Feb 1972

8.5 Ice Protection

All commercial aircraft for which all weather certification is desired must comply with the ice protection provisions of Part 25 of the FAA regulations. STOL aircraft will normally fly shorter ranges than CTOL aircraft and thus spend a higher percent of their operating time at lower altitudes where severe icing is more frequently encountered. Thus, icing conditions which exceed the specified standards will be encountered more often. The freezing rain/drizzle, that is found more often at the lower altitudes, is not covered in the current regulations. There is concern that STOL aircraft requirements for visibility, controllability, and performance may be more sensitive to ice accumulation than CTOL aircraft and, therefore, current regulations may not provide proper safety margins for STOL.

- Tests are required to show the effects of icing and to determine where icing protection will be required on the various lift system components, such as: leading edge flaps and slats, high deflection trailing edge flaps, direct lift and direct drag controls, and the leading edge of the augmentor wing upper flap. The meteorological standards and methods of showing compliance with safety regulations will require a thorough study as applied to STOL aircraft operating conditions.

8.6 Airports and Operations

The outward physical appearance of the future ground level airports for STOL short-haul aircraft are not expected to be greatly different from the trunk-airports of today except for airport size. Full STOL system operation is dependent on incorporation of the necessary ATC, runway, terminal, and access improvements on a timely basis. It is unclear whether the future STOL short-haul airports should have a Category III Microwave Landing System. Also unknown are the economic benefits to the airlines for increased flight schedule reliability that such a system would provide.

- A study should be made of the cost benefits of the MLS Category II and III systems for use in the STOL short-haul market.

Fog is the major cause of low ground visibility. Various fog dispersal systems have been tested using chemicals, and heat from jet engines.

- Research is required on fog dispersal systems to improve their performance and to reduce their costs. The system should then be analyzed and compared with the costs associated with Category III capability.

In many locations, ice and snow on the runway can disrupt or curtail operations for periods up to several days. This results in airline operating losses and unreliable service to the traveler.

- Research is required to determine the most efficient way to remove ice and snow. It is suggested that some method of heating

the runway might be found to be feasible. There is also the possibility that the fog dispersal heating unit discussed previously could be integrated with the runway ice and snow removal system.

- o The trailing vortex that will be generated by STOL aircraft may produce a powerful turbulent wake. Investigations will be required of propulsive-lift aircraft to determine safe separation distances for all modes of operation.

The indirect operating costs (IOC) associated with airline operations appears to be a fruitful area for study. These costs show dramatic differences between various airline operations.

- o Studies are needed to examine ways of reducing the IOC which may lead to new automated ways of interfacing the passenger and his baggage with the aircraft. This would include ticketing, baggage handling, and people-movers.

9.0 MILITARY/COMMERCIAL COMMONALITY

A study was conducted to investigate the economic tradeoffs of military/commercial commonality. A transport designed to meet a typical military STOL transport mission is shown in Figure 9-1. From this design, a commercial transport was derived, as shown in Figure 9-2. The characteristics of these aircraft are compared in Table 9-1. The field lengths for the two aircraft were calculated to different ground rules, i.e., the military aircraft was designed to the military takeoff and landing requirements, while the Model 24C meets the criteria used for commercial STOL aircraft in Phase II. The military STOL transport is an externally blown flap configuration powered by four advanced technology engines with a bypass ratio of six, and no acoustical treatment.

The commercial derivative airplane (Model 24C) has an engine which used the same engine core as the military transport. The military engine which has a fan pressure ratio of about 1.6, is replaced with a commercial engine using a variable pitch fan with a 1.32 fan pressure ratio. With acoustical treatment lining the internal nacelle walls, and without treated rings, the aircraft has an estimated noise level of 102 EPNdB at 500 foot (153 m) sideline, assuming 1980 technology.

The military STOL transport fuselage has a diameter of 216 inches (5.5 m) which allows a double aisle, 8-abreast seating in the commercial version. The military aircraft was typical of cargo configurations featuring low cargo floors to facilitate loading through a rear clam-shell door. Although the same shell size is used in the commercial aircraft, the floor is located higher which permits space for baggage, cargo and landing gear

retraction into the belly compartment.

The wing, vertical and horizontal tail are 100 percent common. Some of the other components, such as, wing and tail attach structure in the fuselage, the pilot's compartment, flight controls, and the various systems have commonality in varying degrees. A detailed weight breakdown of the two aircraft showed that 44.5 percent of the commercial cost weight and 48.6 percent of the military cost weight are common parts of the two aircraft. The common engine core weight is not reflected in the weight breakdown since dry engine weight is not considered in cost weight totals.

It should be noted that the Model 24C is quite different from the 150 passenger, 3000 ft. (915 m) field length baseline study aircraft. There are differences in fuselage cross section, wing area, aspect ratio, thrust to weight ratio and wing loading, to name a few. The study baseline aircraft is more optimum for the short-haul mission, while the Model 24C with its extra thrust, larger wing, and wider fuselage has a greater potential for stretching both range and passenger payload.

Economic studies (Volume V) showed that an aircraft such as the Model 24C would cost approximately 5% less in a combined military/commercial program and that airframe development costs could be reduced by approximately 50%. These costs are based on a 400 unit production for the commercial aircraft and assumed engine commonality only in the engine core. These costs do not include engine development. The commercial program, for noise reasons, had to bear the costs of development of a high bypass ratio variable pitch fan thereby reducing the potential cost saving. The attractiveness of commonality would obviously be enhanced if the military and commercial aircraft could be designed to use the same power plant.

MILITARY STOL TRANSPORT

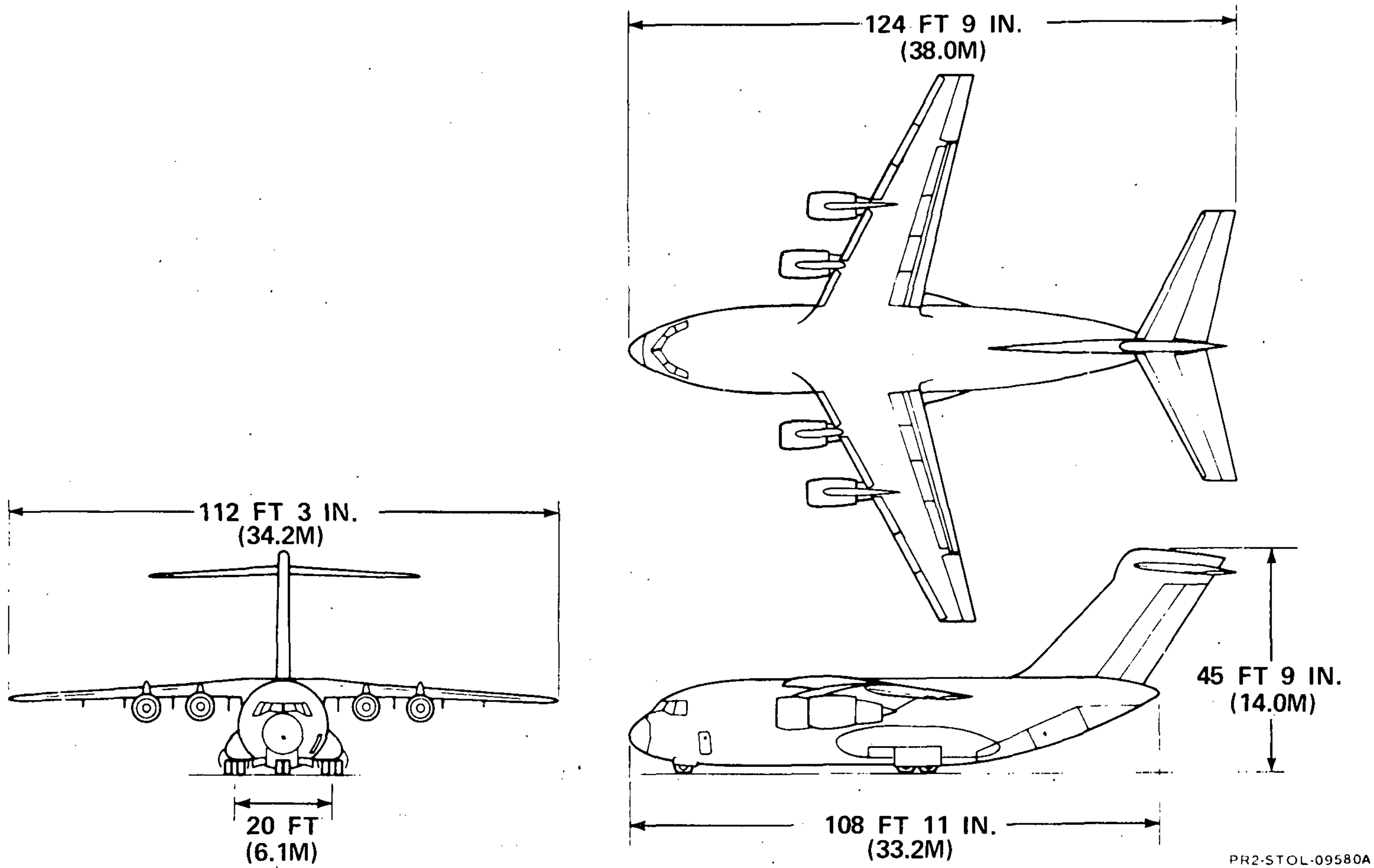


FIGURE 9-1.

MODEL 24C

GENERAL ARRANGEMENT

COMMERCIAL DERIVATIVE OF MILITARY TRANSPORT

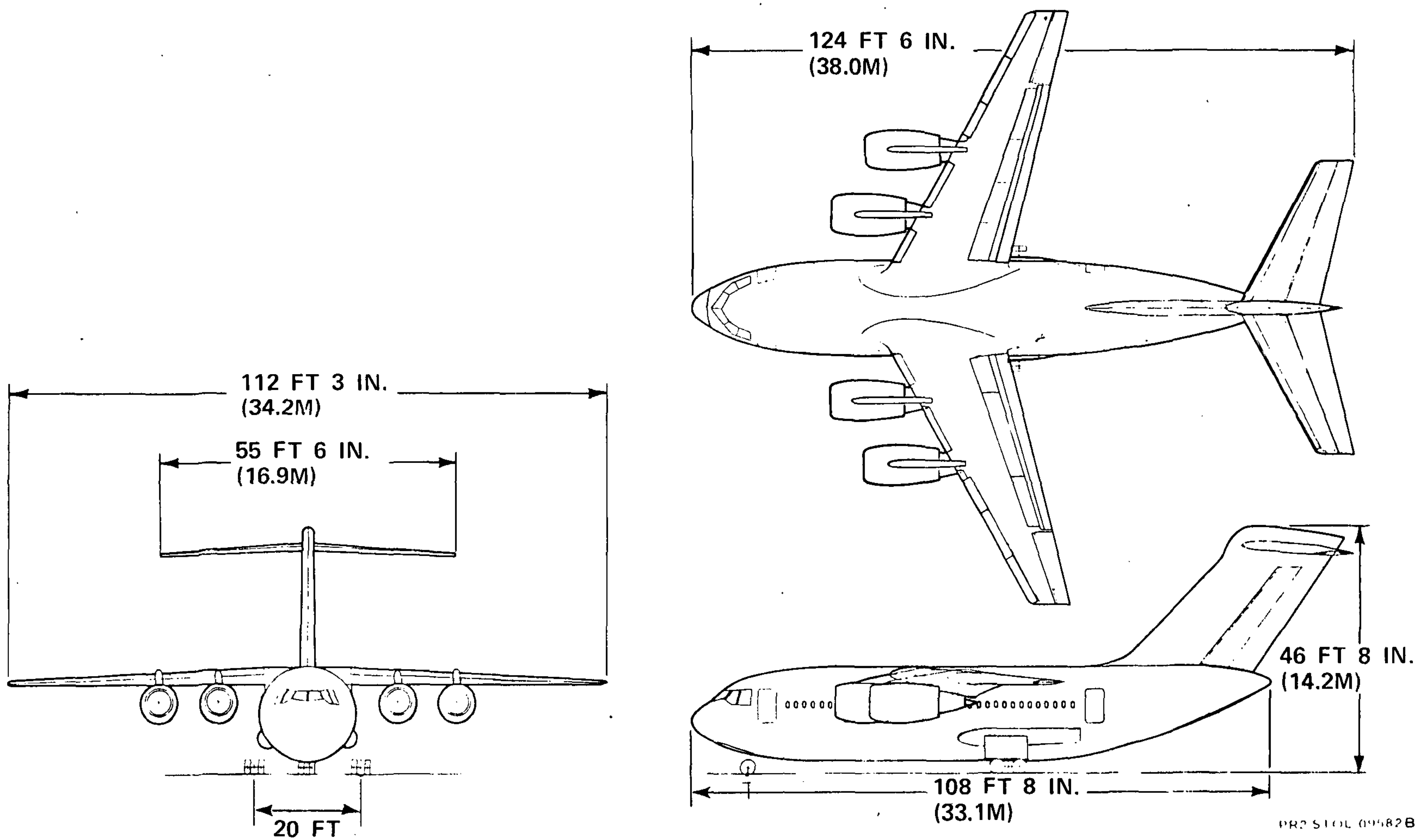


FIGURE 9-2

TABLE 9-1

AIRCRAFT CHARACTERISTICS

Military STOL Vs Model 24C

		MILITARY STOL		MODEL 24C	
Takeoff Gross Weight	lb (kg)	146,000	(66,220)	164,350	(74,550)
Operational Empty Weight	lb (kg)	101,530	(46,050)	113,560	(51,510)
Payload	lb (kg) - psgr	28,000	(12,700)	151	
Wing Area	ft^2 (m^2)	1,800	(167)	1,800	(167)
Wing Loading	lb/ft^2 (kg/m^2)	81.1	(396)	91.3	(446)
Aspect Ratio		7		7	
Engine Thrust	lb (n)	18,900	(84,070)	24,000	(106,760)
T/W		0.493		0.584	
Field Length	ft (m)	2,000	(610)	2,700	(823)
Design Range	st m (km)	575	(926)	575	(926)
Cruise Mach No.		0.75		0.78	
Cruise Altitude	ft (m)	30,000	(9,144)	28,000	(8,534)
DOC	¢/ASSM (¢/ASKM)	--		2.15	(1.34)

10.0 CONCLUSIONS

A comprehensive interdisciplinary systems evaluation approach was used throughout the study responding to the complex interaction among markets, aircraft, airports, economics and systems operations in analyzing the characteristics of a national short-haul air transportation system operational during the 1980-1990 period. In view of the depth and breadth of the study, as well as the commercial air transport realism with which it was conducted, the conclusions drawn from the study help provide a sound basis for future government and industry research and development necessary to achieve STOL air transportation.

The major conclusions of the study are:

- STOL AIRCRAFT CHARACTERISTICS
  - STOL transportation systems appear to be economically viable.
  - Despite higher direct operating costs relative to CTOL, 150 passenger, 3000 foot STOL designs showed potential returns on investment of 20 percent.
  - Returns on investment for STOL 2000 foot designs varied from 8.5 to 12.5 percent. The need for this short field length is questionable, since the airport analysis indicated that a 3000 foot capability was available at almost every site examined.
  - A payload of approximately 150 passengers is the preferred size for the midpoint of the 1980-1990 period. This size is a proper balance between the economic advantage of larger payloads and the marketing benefits of schedule frequency.

- For the short haul stage lengths studied, the block times were essentially insensitive to cruise speed.
- Development of a new high-bypass-ratio, quiet, clean variable pitch fan engine in the 20,000 pound thrust class is required.
- Mechanical flap aircraft improve with field length and are competitive with propulsive lift aircraft for 3000 foot field length .
- Propulsive lift 2000 foot and mechanical flap 3000 foot aircraft require ride quality improvements.

- MARKETS
  - The United States civil market for a 150 passenger STOL short-haul aircraft is estimated to be:
    - 420 aircraft by 1985 for the representative national system which includes high-, medium- and lower-density city pairs.
    - 240 aircraft by 1985 and 320 aircraft by 1990 based on the higher-density city pairs alone.
  - The foreign civil market for the same aircraft, based on the higher-density city pairs alone, is estimated to be 320 aircraft by 1985 and 545 aircraft by 1990.

- NOISE
  - The cost of noise reduction runs high -- particularly to reach the noise level established in this study as a goal (95 PNdB at 500 feet sideline distance).

- o All STOL designs provided significant noise reduction over current CTOL aircraft.

- IMPLEMENTATION
  - o There are numerous existing airports which are favorably located to implement a STOL transportation system.
  - o The earliest date for implementation of propulsive lift aircraft in an operating system is the 1982-83 period.

11.0 Appendix

STOL AIRPORTS

CODE	AIRPORT	CITY
ABQ	Albuquerque Sunport	Albuquerque
ACV	Arcata	Eureka
AGC	Allegheny County	Pittsburgh
AMA	Amarillo Air Terminal	Amarillo
AUS	Robert Mueller Municipal	Austin
BED	Hanscomb Field	Boston
BEL*	Beltsville	Baltimore
BHM	Birmingham Municipal	Birmingham
BKL	Burke Lakefront	Cleveland
BNA	Nashville Metropolitan	Nashville
BOI	Boise Air Terminal	Boise
BUF	Greater Buffalo	Buffalo
CAE	Columbia Metropolitan	Columbia
CGX	Meigs	Chicago
CHS	Charleston Municipal	Charleston
CLT	Douglas Municipal	Charlotte
CMH	Port Columbus	Columbus
CPS	Bi-State Parks	St. Louis
CRP	Corpus Christi Int'l	Corpus Christi
CVG	Greater Cincinnati	Cincinnati
DAL	Dallas Love Field	Dallas
DAY	J. M. Cox	Dayton
DCA	Washington National	Washington
DEN	Stapleton International	Denver
DET	Detroit City	Detroit
DSM	Des Moines Municipal	Des Moines
ELP	El Paso International	El Paso
EMT	El Monte	El Monte
EUG	Mahlon Sweet Field	Eugene
FAT	Fresno Air Terminal	Fresno
FLL	Hollywood International	Ft. Lauderdale

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CODE	AIRPORT	CITY
FTY	Fulton County	Atlanta
GDS *	Gen. D. Spain	Memphis
GEG	Spokane International	Spokane
GPF *	Gen. Patton Field	Los Angeles
GSO	Greensboro High Pt.	Greensboro
HFD	Hartford-Brainard	Hartford
HOU	Houston Hobby	Houston
HPN	Westchester County	New York
ICT	Wichita Municipal	Wichita
IND	Weir Cook	Indianapolis
ISP	Islip MacArthur	New York
JAN	A. C. Thompson Field	Jackson
JAX	Jacksonville International	Jacksonville
LAS	McCarran International	Las Vegas
LBB	Lubbock Regional	Lubbock
LGB	Daugherty Field	Long Beach
LIT	Adams Field	Little Rock
MAF	Midland Odessa Regional	Midland Odessa
MCO	McCoy Air Force Base	Orlando
MDW	Midway	Chicago
MIC	Crystal	Minneapolis-St. Paul
MKC	Kansas City Municipal	Kansas City
MKE	Gen. Mitchell Field	Milwaukee
MOB	Bates Field	Mobile
MOF *	Moffett Field	Mountain View
MRY	Monterey Pennisula	Monterey
MYF	Montgomery Field	San Diego
NEW	Lakefront	New Orleans
OAK	North Field	Oakland
OKC	Will Rogers World	Oklahoma City
OMA	Epply Field	Omaha
OPF	Opa Locka	Miami
ORF	Norfolk Regional	Norfolk

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CODE	AIRPORT	CITY
CWD	Norwood	Boston
FDK	Dekalb Peachtree	Atlanta
PDX	Portland International	Portland
PHF	Patrick Henry	Newport News
PHX	Phoenix Sky Harbor	Phoenix
PNE	North Philadelphia	Philadelphia
PVD	Greater Providence	Providence
RDU	Raleigh/Durham	Raleigh Durham
RHV	Reid Hillview	San Jose
RIC	R. E. Byrd International	Richmond
RNO	Reno International	Reno
ROC	Monroe County	Rochester
SAC	Sacramento Executive	Sacramento
SAT	San Antonio International	San Antonio
SAV	Savannah Municipal	Savannah
SBA	Santa Barbara Municipal	Santa Barbara
SDF	Standiford Field	Louisville
SEA	Seattle-Tacoma	Seattle
SEC*	Secaucus	New York
SHV	Shreveport Regional	Shreveport
SLC	Salt Lake City Int'l	Salt Lake City
SNA	Orange County	Santa Ana
SYR	C. E. Hancock	Syracuse
TLH	Tallahassee Municipal	Tallahassee
TOL	Toledo Express	Toledo
TPA	Tampa International	Tampa
TUL	Tulsa International	Tulsa
TUS	Tucson International	Tucson
TYS	McGhee Tyson	Knoxville
VNY	Van Nuys	Van Nuys

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